DEVELOPMENT OF ADVANCED DESIGN CRITERIA FOR STRONGER LATTICE TOWERS

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Degree of Doctor of Philosophy

Department of Civil Engineering

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Thesis submitted in partial fulfillment of the requirements for the degree Doctor of Philosophy of Engineering in Civil Engineering

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Declaration of the candidate & Supervisors

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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The above candidate has carried out research for the PhD thesis under our supervision.

Name of the supervisors: 1. Prof. M.T.R. Jayasinghe

2. Dr. C.S. Lewangamage

Signature of the supervisors: 1. Date:

2.

Abstract

The key lateral loads acting on a freestanding telecommunication/broadcasting tower are due to wind effects though occasionally seismic forces also can act. Though earthquake design guidelines are well covered directly or indirectly in many tower designs standards, telecommunication/broadcasting towers in Sri Lanka and in Indian subcontinent are not specifically designed for earthquake induced forces. Therefore, a detailed study was undertaken to determine the probable structural performances that can be expected from commonly adopted Four leg and Three leg self supporting lattice towers. For this study, the earthquake levels that can be possibly expected in Sri Lanka and in the South Asian region have been considered.

A key parameter that can directly affect the seismic performance is subsoil conditions. Hence, a probable range of subsoil conditions have been considered in this study as certain subsoil conditions could amplify seismic waves under certain conditions. For a range of tower heights that are generally used, Response Spectrum analysis techniques have been used to assess the probable performance of lattice towers. An assessment was also made with equivalent static method to determine the applicability of it over a wide range of conditions.

One of the key observations has been that the earthquake induced stresses on key members of lattice towers could be of lower magnitude than due to effects of wind. The parameters that could affect the seismic behaviour of a lattice tower are the subsoil stratum and the natural period of vibration of the lattice tower.

The main finding of seismic analysis of lattice towers is that for the likely seismic hazard levels in Sri Lanka, key elements of towers will be subjected to much lower stress levels than induced by the winds of design magnitudes. However, if more severe earthquakes that could occur in the South Asian region are considered, there is a possibility for the earthquake induced forces to reach structurally significant levels. However, still such forces are less than the wind induced forces.

For both earthquake and wind induced lateral loads, one of the key elements that needs careful attention is the connection of the tower to the foundation through baseplates. Baseplates are crucial elements related to structural stability of self supporting lattice towers. It acts as the interface between the tower body and the foundation.

Due to structural characteristics of towers, uplift forces induced on baseplates govern the design of the baseplates. This is a rare case to occur on baseplate of buildings and other conventional structures. Hence, guidelines published in design codes and standard text books for design of baseplates are not really applicable for self-standing towers. This is a gray area that needs attention. Hence, an extensive study was carried out in this regard using Yield line theory to develop a design guideline. The developed theory was verified through a detailed experimental investigation and a finite element modeling using computer aided non liner modeling techniques. The formulae developed were modified for industrial applications considering all practical deviations which could not be addressed under fundamental theory using extensive parametric analyses carried out with the Finite Element models. The findings have been presented as design guidelines in the form of equations that can be used by structural design engineers undertaking free standing tower designs.

Keywords: Telecommunication towers, earthquakes, response spectrum analysis, baseplates, finite element analysis, design guidelines

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Finally, there is one outstanding person behind my whole successful journey even though he is not physically present now. It is his vision and passion that drove me to this peak. I dedicate this thesis to him, to my dear farther.

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Abbreviation	Meaning
4G	Fourth generation of broadband cellular network technology
5G	Fifth generation of broadband cellular network technology
ANSI	American National Standards Institute
BNBC	Bangladesh National Building Code
BS	British Standards
GDP	Gross domestic product
EHV	Extra High Voltage
GSHAP	Global Seismic Hazard Assessment Programme
GSM	Global System for Mobile Communications
GSMB	Geology Survey and Mining Bureau of Sri Lanka
IS	Indian Standards
LTE	Long-Term Evolution
NBC	National Building Code of Nepal
MMI VIII	Modified Mercalli intensity scale 8
PGA	Peak Ground Acceleration
PSHA	Probabilistic Seismic Hazard Assessment
SODF	Single Degree of Freedom
SPT	Standard Penetration Test
SRSS	Square Root Sum of Squares
TRCSL	Telecommunication Regulatory Commission of Sri Lanka
TIA	Telecommunications Industry Association