

**VULNERABILITY ASSESSMENT OF RURAL
HOUSES DUE TO CYCLONIC WIND**

PRADEEP K. GOYAL



**CENTRE FOR RURAL DEVELOPMENT & TECHNOLOGY
INDIAN INSTITUTE OF TECHNOLOGY, DELHI**

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**VULNERABILITY ASSESSMENT OF RURAL
HOUSES DUE TO CYCLONIC WIND**

By

PRADEEP K. GOYAL

Centre for Rural Development & Technology

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Dedicated to Lord Shiva

Certificate

This is to certify that the thesis entitled, “**Vulnerability Assessment of Rural Houses due to Cyclonic Wind**”, being submitted by **Mr. Pradeep Kumar Goyal**, to the Indian Institute of Technology, Delhi, for the award of ‘**DOCTOR OF PHILOSOPHY**’ is a record of the bonafide research work carried out by him under our supervision and guidance. He has fulfilled the requirements for submission of this thesis, which to the best of our knowledge has reached the requisite standard.

The material contained in the thesis has not been submitted in part or full to any other University or Institute for the award of any degree or diploma.

(Prof. T. K. Datta)
Professor
Department of Civil Engineering
Indian Institute of Technology
New Delhi – 110016, India

(Dr. V. K. Vijay)
Associate Professor
CRDT
Indian Institute of Technology
New Delhi – 110016, India

October, 2009

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(Pradeep K. Goyal)

Abstract

All rural houses in the coastal regions of developing and underdeveloped countries are prone to severe damages due to cyclones. Very few studies in estimating the vulnerability of such houses to cyclonic wind have been reported in the literature. The main reason for this lack of study is the scarcity of the recorded data on the cyclonic wind speeds and consequent damage scenarios. The reported literature on the subject dealt with the procedure for the vulnerability assessment of low cost and low rise buildings having clearly identified components. Unfortunately, in developing countries like India, the rural houses are mostly of non-engineered type in which clear demarcation of different components of the house is not possible. Further, there is no systematic recorded data on the damage scenarios and cyclonic wind speeds. The present work is motivated to develop some methodologies which can be used to assess the vulnerability of rural houses to cyclonic wind speed in countries like India and also to provide cyclonic risk assessment of coastal regions. For this purpose, a number of studies have been presented in the thesis. They include (i) cyclonic microzonation of coastal regions and (ii) three different procedures for assessing the vulnerability of rural houses to cyclonic wind.

The method for cyclonic microzonation of coastal regions uses the recorded cyclonic tracks rather than the wind speeds which are not generally available. From the cyclonic tracks, the wind speeds are calculated for a particular site and cyclonic hazard curve for the site is developed using probabilistic approach. The region to be microzoned is divided into a number of grids. The centres of the grids are taken as the sites. Surrounding a site, a circle of specified radius is constructed for obtaining the wind speeds at the site due to cyclone tracks passing through the circle. Microzonation maps are presented in terms of the design wind speed of specified return periods. As numerical

examples, the states of Andhra Pradesh and Orissa are considered and have been microzoned for cyclonic wind speed.

For the vulnerability assessment of rural houses, the first procedure is developed for finding the overall vulnerability of a cluster of rural houses using direct approach. In this approach, different observed damage states quantified as minor, moderate and extreme damages are defined rather than component damages by defining the probability of failure of different damage states in terms of failure velocities, n^{th} percentile fragility curve showing the overall probability of failure to cyclonic wind speed is then obtained by integrating the distribution of the cyclonic wind speed with the failure distribution.

The second procedure uses component based approach in which the failures of different components of the houses are described in terms of probability distributions of wind velocity. The method obtains different damage states by combining different possible damage scenarios and, accordingly, a damage probability matrix is determined. The matrix shows the joint probability of the damage states for different wind speeds. By using convolution technique, the vulnerability curves showing the annual mean damage with mean yearly maximum wind speed are obtained for a cluster of different types of houses.

The third procedure modifies the second approach by including wind directionality effect. The effect of wind direction on the damage of structures is difficult to include in the analysis because of the non-availability of enough data regarding the failure of the components of the houses for directional wind. As a result, some simplified methods have been developed. These methods are extended to modify the second approach of vulnerability assessment. The wind directionality effect is incorporated in two different ways. In the first case, an equivalent directional effect is used to modify the component failure velocities. In the second case, component failure velocities are

converted into direction dependent failure velocities by finding a wind directional factor for each direction. For convolution, sixteen wind directions are considered, and the joint probability distribution between wind speed and direction is used. The resulting vulnerability curve is, thus, modified due to the directional effect.

The above procedures are applied to find the vulnerability of a cluster of hundred rural houses in India. The effects of important parameters like ratio of non-engineered to semi-engineered houses, distributions of wind speed and distributions of failure velocity of damage states, coefficients of variation of failure velocity and the wind speed, etc. on the annual mean damage or the probability of failure are investigated.

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