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An Understanding of Tree Biomechanics in the Context of India

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ABSTRACT: Mechanical behavior of trees is the one of the prime interest for urban forestry and arboricultural research. Tree biomechanics deals with the study of mechanical responses offered by the standing tree to the external dynamic load (primarily wind) and static load (crown load). It helps in understanding the phenomenon about how the tree survives in strong winds and further assist in monitoring the urban forest with minimal danger to human life and properties due to tree felling. Therefore, modeling the tree behavior and measuring the actual state of trees in situ condition is important for the tree safety assessment. Tree biomechanics study in India is very limited, that too particular to Wind break plantation (Buvaneswaran *et al.*, 2016) and shelter belt (Petty, 1981) study in agricultural field. These studies are related to wind effect on agricultural crops and not to the impact on standing trees. With the advancement of cities and the concept of urban forestry in India, there is a need for development of Wind-Tree modeling software through which we can assess the trees' health status and stability against the wind.

Keywords: Tree Biomechanics, wind tree modeling, wind Speed, Crown Size.

INTRODUCTION

Biomechanical studies on trees adopt two comprehensive approaches: statics and dynamics. The major subject of discussion in this field with respect to risk assessment of the forest due to winds in order to prevent economic and life losses is the relationship of tree biomechanics with that of tree architecture. Development of accurate model to predict the impact of wind on tree bending or breakage requires comprehensive understanding of tree structure, tree size, root anchorage, mechanical properties of stem (Brüchert & Gardiner, 2006). Several researchers (Mamada *et al*, 1984; Morgan & Cannell 1987; Milne and Blackburn, 1989; Spatz and Bruechert, 2000) have applied beam bending concepts to understand the static mechanical behavior and vertical stresses in the standing trees. Trees correspond to dynamic systems and their response to mechanical load varies with time. Many works have been done to understand the dynamic component (damping, swaying) of trees due to their interaction with wind. According to Gardiner, 1992 tree responds the most to the wind having frequency close to the resonance frequency of the tree. Biomechanical studies using dynamic methods have shown that the tree's form influences dynamic response in winds and differences in morphology of tree can produce extreme critical dissipation of stem oscillations. Rather than tree species, tree morphology better explains response of tree to wind in urban trees. A method for biomechanical studies has been devised by James *et al*, 2017 that uses optical strain measurement technique in which small dots (speckle) are sprayed on tree surfaces to observe the strain distribution on trunks and branches under load. Understanding the behavior of trees in strong winds (Mayer, 1987; Gardiner, 1994, 1995; Peltola, 1996; Gardiner *et al.*, 1997) and root anchorage mechanisms (Deans and Ford, 1983; Coutts, 1986; Ray and Nicoll, 1998) it has become possible to develop mechanistic models that predict the critical wind speeds that cause damage trees in urban areas. Such approach facilitates predictions of the impact of any urban forestry operations on trees' stability and assists in designing of Slivicultural strategies for reducing wind damage. In a static system the breaking and uprooting forces are usually calculated as bending moments at the base of the stem. They are treated in two ways. Firstly, the force produced by wind action on the crown, simulated by pulling with a rope that causes deflection of the stem. The leaning stem then assists in uprooting the tree because its centre of gravity moves over the hinge point in the root system (Ray and Nicoll, 1998), Mattheck, 1995) (Fig. 1&2).

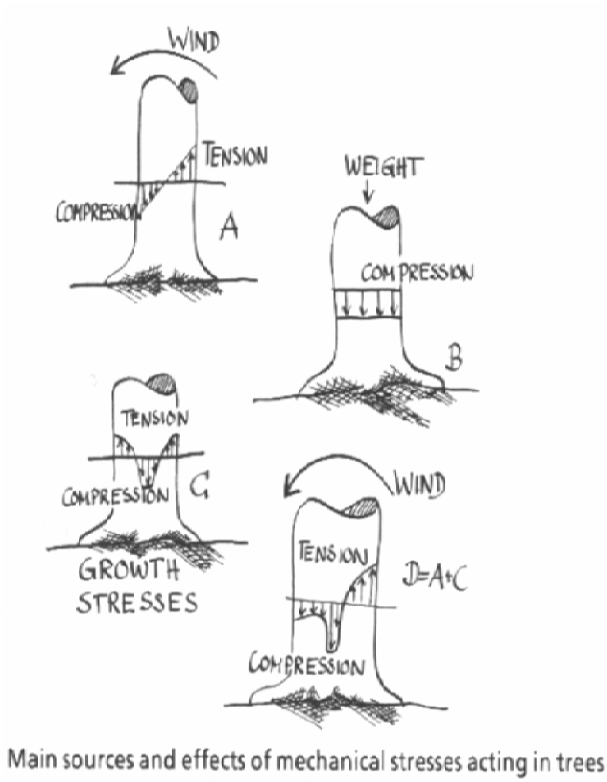

Fig. 1. Load applied to tree.

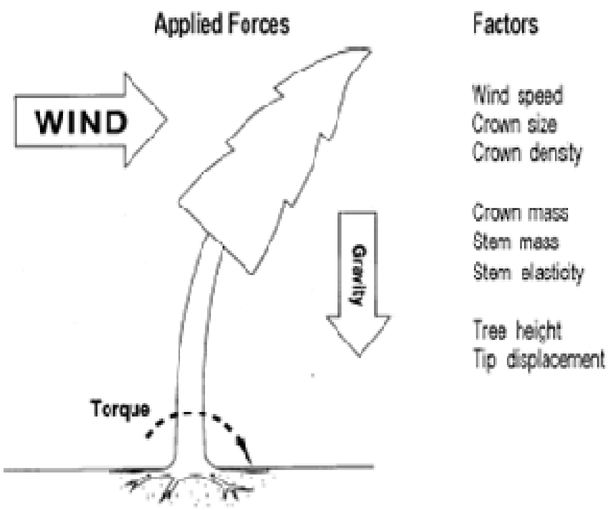

Fig. 2.

In turn, the second force is applied by the weight of the stem and crown. The bending of tree stem is resisted by the uprooting moment and various components of root anchorage: the weight of the root soil plate, the strength of the windward roots, the strength of the root hinge and the soil strength at the base of the root-soil plate. If the uprooting moment exceeds the resistive bending moment of the tree at a particular angle of deflection, the tree will deflect further.

The tree falls down if the uprooting moment exceeds its maximum resistive bending moment, with the relative strengths of the stem and it's based on the ultra-structure of the wood (Astley *et al*, 1997) (Fig. 3) and roots determining the mode of failure (Petty and Worrell, 1981).

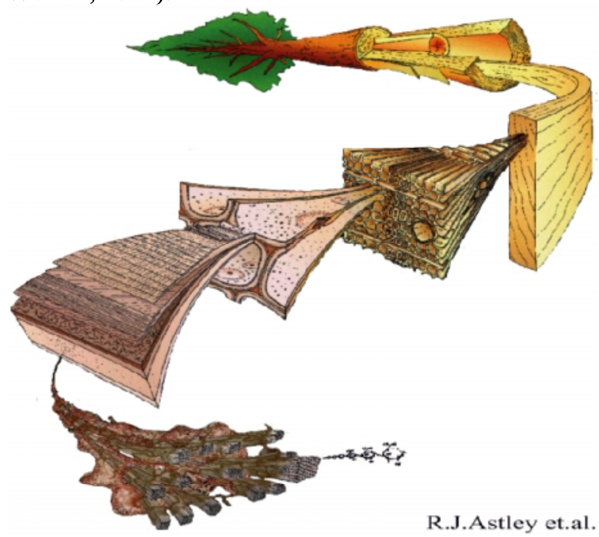

Fig. 3. Ultra structure of wood (Astley *et al.*, 1997).

NEED OF TREE BIOMECHANICS STUDY IN CONTEXT OF INDIA

India is geographically divided into six wind zones on the basis of long-term meteorological data. With considerably varying wind speeds in the six zones, important Indian cities are in the moderate damage (44 m/s) to Very high Damage zone (>50m/s). Especially in the coastal cities (Chennai, Vizag, Bhubaneswar, Mumbai etc) a lot of damage to the properties through falling of huge trees during cyclone period has been reported after every cyclone. In northern part of India, heavy wind is felt during monsoon period (June-Aug). But in southern part of India, it occurs during monsoon and retreat of monsoon periods (Oct-Dec). Natural forest or bunch of plantation can reduce the effect of heavy speed wind but in case of small patches or individual trees (as in urban areas) it will affect badly. In India, mostly roadside plantation practice is followed to raise urban forest. These individual roadside trees are the most affected ones during cyclone period (Fig. 4).

India primarily comprises of tropical forest tree species and most of the wind tree modeling has been developed on temperate forest tree species. Tropical species are broad leaved trees having different crown size and heavy wood material. They cannot be governed by the biomechanics model developed for temperate species. Therefore, we need to study and model biomechanics of tropical species (Niklas, 2016) and that too particular to India.

Fig. 4. Wind zone of India (IS 875(3)-1987 based on IMD data).

Assessing the safety of a tree, like that of any engineering structure, is a clearly defined engineering task with generally accepted rules. It involves determination the forces occurring as accurately as possible on one hand and on other hand it needs to determine whether the structure and material can withstand them. Generally less crown density trees with low trunk height and deep root with well drained soil can with stand the wind (Peter Horacek, 2003) (Fig. 5) but provided the trunk should be free from decay.

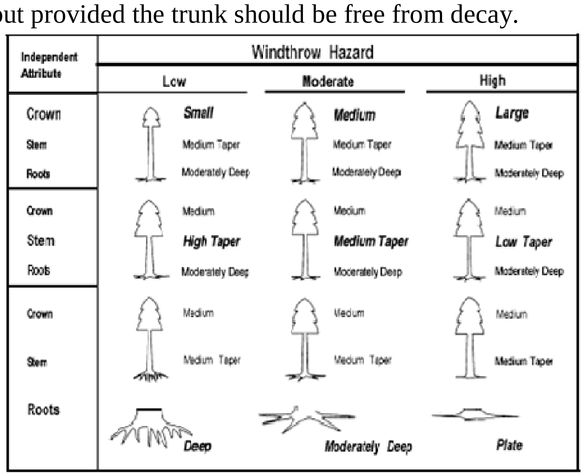

Fig. 5.

The procedure is symbolized in the statics triangle (Fig. 6), which consists of the inseparable connection of loads, tree geometry and wood properties. If nature had kept closely limited numerical values which could be used to describe a uniform residual wall-thickness or a constant safety stress valid for the entire tree, it would have been simpler to determine the safety of trees. Since trees consist of roots, stem and crown that are optimized by adaptive growth, their diversity suggests that it would not be possible to determine safety by generalized numerical values characterizing the degree of hollowness or safety without any measurements.

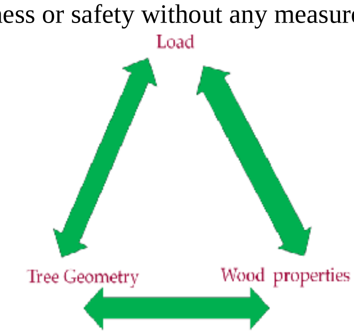

Fig. 6.

Apart from external factors, biological factors also damage the tree trunk by decaying the heart wood (hollowness). In this line, Timber mechanics discipline of FRI, India has devised the tools for testing the hollowness of the tree trunk by non destructive technique (ultrasonic). It reveals the size of the hollowness (Fig. 7). In this context, we are moving towards optimizing the minimum wall thickness of the trunk (hollowness) which can resist maximum wind velocity in order to identify hazardous trees and cull on time.

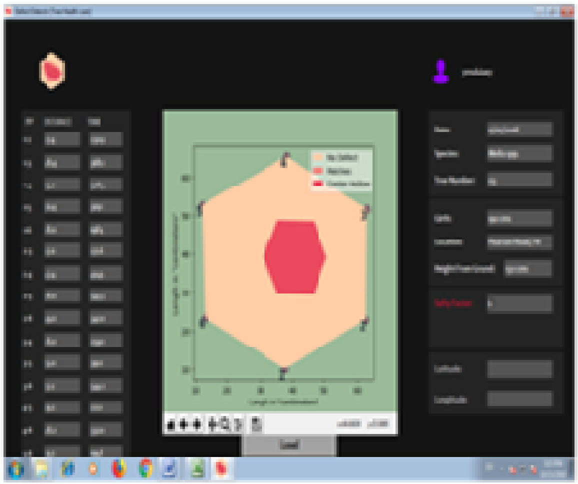

Fig. 7.

CONCLUSION

Tree Biomechanics study is the new field in India. Indian city municipal corporation are not much bothered about the tree falling and its damage to the properties because of its less cyclone/storm occurrence in the city earlier but now a day's cyclone are more common, frequency is high per year and high rain intensity so that the damage to the properties by means of falling trees during last decades was more. In 2020, India received the four cyclones (Amphan, BOB 03, Nisarga and Nivar**).** We should be more focused and emphasis our study on the designing of city based on the wind effect. Based on above fact and discussion following suggestion and further scopes were elucidated in the paper.

- Important Indian cities should be mapped according to the health status of the trees through technology intervention. If heavily decayed trees are found, they should be removed and new seedlings should be planted.
- Tall and heavy broad canopy trees should not be planted in urban areas. Only wind resistant trees like *Casuarina***,** *Eucalyptus* or otherwise cone shape crown trees should be preferred.
- Less leaf area index trees can be planted so that infiltration of wind through the tree canopy will be more, example-*Tamarindus indica*,
- All the municipality corporation of Indian cities should have an exclusive post for urban silviculturist. Through them only selection of appropriate trees based on the wind data for the particular region/city should be done.
- Periodically, health status of urban forest trees needs to be checked with the help of Forest Research Institute or State Forestry College by reliable technologies.
- More focus should be given to research on urban tree biomechanics and development of the Wind Tree Modeling software through which easy assessment can be done the trees which can with stand stability against wind.

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