# Wind Engineering in Sri Lanka – Past, Present and Future

C. S. Lewangamage[a], A. U. Weerasuriya[b], M. T. R. Jayasinghe[c]

[a] *Senior Lecturer, Department of Civil Engineering, University of Moratuwa, Sri Lanka*
[b] *Research Assistant, Department of Civil Engineering, University of Moratuwa Sri Lanka,*
[c] *Professor, Department of Civil Engineering, University of Moratuwa,Sri Lanka*

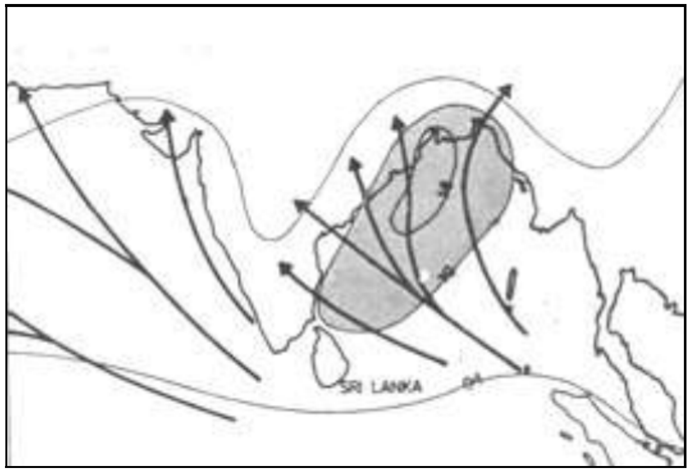
ABSTRACT

This paper refers to historic development of wind engineering in Sri Lanka. The tropical cyclones that passed through the island during the last three decades and damages caused by them as well as other severe wind conditions have also been include. The aspects and techniques of design manual "Design of Buildings for high winds – Sri Lanka" is briefly discussed. The paper highlights the actions that were taken by Sri Lankan Government in order to increase the awareness and improvement of wind engineering in Sri Lanka. Various past research activities and ongoing research projects are discussed with details. Proposed future wind engineering projects in Sri Lanka are also presented in this paper.

KEY WORDS: Tropical cyclones, Design manual, Wind zones, Wind energy

## 1.0 INTRODUCTION

Sri Lanka is an island of about twenty million population situated in the Indian Ocean, at the base of the Indian sub continent, 880 km north of the equator. This pearl shaped island has a maximum length and width of 435 km and 240 km respectively, covering up a land area of 65,525 $km^2$. It is surrounded by the Bay of Bengal in north direction and by the Indian Ocean on its eastern, western and southern flanks. The Bay of Bengal is one of the places with the severest wind actions on the planet earth. Thus, the country could face highly destructive wind actions during the North Indian cyclone season and the monsoon seasons annually (Figure 1). Most of the cyclones enter the country from its Northeast, East and Southeast coasts. Because of the diminutive size of the island, most of its parts may fall into danger of getting adverse affects by cyclones. Most of the economic and social centers that are located in the coast line and hence they are densely populated and highly industrialized as well. Thus, sudden cyclone strike in the coastal area will lead to severe disasters that force the society into disarray. Thus since about three decades Sri Lankan government and Sri Lankan researchers have actively promoted research to develop wind engineering application as indicated in this paper.




0.1 – 1.0    1.0 – 3.0

1.8 Isoline of maximum frequency    Preferred tracks

Figure 1.Windstorm risk (Tropical storms and cyclones number per year)

## 2.0 PAST WIND ACTIONS IN SRI LANKA

Because of the geographical location of the island, tropical cyclone path of the Bay of Bengal lies in the vicinity to the East and Northeast coastal areas. These areas have undergone severe effects during the past, due to the above mentioned cyclones. The cyclones that have gone through the island since 1900 are shown in Table 1.

Table 1. Time, situation and origin of cyclone in 1900 – 2000 periods

| No | Year/Month | Situation | Origin |
|---|---|---|---|
| 1 | 1906 January | Cyclone Storm | 07.5N, 84.5E |
| 2 | 1907 March | Severe Cyclone Storm | 08.5N, 86.5E |
| 3 | 1908 December | Cyclone Storm | 07.5N, 83.5E |
| 4 | 1912 December | Cyclone Storm | 05.5N, 82.5E |
| 5 | 1913 December | Cyclone Storm | 06.5N, 85.5E |
| 6 | 1919 December | Cyclone Storm | 08.0N, 86.0E |
| 7 | 1922 November | Severe Cyclone Storm | 08.5N, 88.5E |
| 8 | 1925 March | Cyclone Storm | 05.0N, 78.5E |
| 9 | 1931 December | Severe Cyclone Storm | 07.5N, 82.5E |
| 10 | 1964 December | Severe Cyclone Storm | 04.9N, 93.0E |
| 11 | 1966 November | Cyclone Storm | 08.0N, 84.0E |
| 12 | 1967 December | Cyclone Storm | 04.0N, 89.0E |
| 13 | 1978 November | Severe Cyclone Storm | 06.5N, 92.5E |
| 14 | 1980 December | Cyclone Storm | 10.5N, 91.5E |
| 15 | 1992 December | Severe Cyclone Storm | 07.5N, 87.2E |
| 16 | 2000 December | Severe Cyclone Storm | 07.5N, 90.0E |

Among those cyclones, the cyclone that occurred in 1978 was the strongest and most devastative one. During this cyclone, the maximum wind speed of northerly 145km/h was recorded at Batticalloa. The same cyclone indicated satellite estimations of 222 km/h of maximum wind speed. Satellite disturbance summary of Washington reported a maximum wind speed of 206 km/h (cyclone events 1900-2000). According to the statistics, about 50% of the roofs of the buildings along the cyclone path were blown off, together with heavy losses to paddy cultivation and coconut tree plantations. This was the worst storm that was to hit Sri Lanka in the last 100 years and the corresponding losses and damages in Northern and Eastern parts of the country were enormous. The Cyclone in year 2000 was the strongest tropical cyclone to strike Sri Lanka since 1978. It was strengthened under fconductive conditions to reach a top wind speed of 75 mph (120 km/h). This cyclone hit Eastern Sri Lanka at its peak strength and weakened slightly while crossing the island before hitting and dissipating over Southern India. The damages due to the cyclones during the last 30 years are shown in Table 2.

Table 2. Cyclone damages in 1978 – 2008 period

| Year | Deaths | Missing | Injured | House Destroyed | House Damaged | Affected |
|---|---|---|---|---|---|---|
| 1978 | 879 | 16 | 375 | 6941 | 74328 | 615176 |
| 1992 | 4 | 5 | 61 | 1600 | 15463 | 91250 |
| 2000 | 6 | 0 | 54 | 9820 | 71851 | 906149 |

Strong winds and gales are occurring more often than cyclones. Many parts of Sri Lanka suffer from these kinds of extreme wind conditions right throughout the year. Fatalities due to gale winds or strong winds are not common in Sri Lanka whereas the property damages are more common incidences. Table 3 is a summary of the damages that occurred due to above two extreme wind conditions and Figure 2 shows some damages caused by it.

Table 3. Damages due to strong winds and gale forces

| Year | Event | Deaths | Injured | House Destroyed | House Damaged | No of people affected |
|---|---|---|---|---|---|---|
| 2006 | Strong Wind | 0 | 12 | 168 | 2130 | 11437 |
| | Gale Force | 3 | 40 | 203 | 1020 | 6184 |
| 2007 | Strong Wind | 9 | 61 | 82 | 2118 | 11012 |
| | Gale Force | 0 | 17 | 6 | 367 | 1972 |
| 2008 | Strong Wind | 0 | 4 | 39 | 1534 | 7887 |
| | Gale Force | 1 | 13 | 7 | 293 | 1327 |

Among the major problems that are associated with these extreme wind conditions are not only the fatalities and property damages. There are some other indirect effects, such as higher precipitation of rain falls, storm surges etc. Areas along the cyclone path may receive higher rainfall that leads to flash floods, landslides and falling of rocks. In cyclone of year 2000, there was a very heavy and widespread rainfall with a storm. The highest rainfall recorded in Trincomalee and Mannar areas with the magnitudes of 276.9mm and 202.1mm respectively. This kind of heavy rainfalls causes massive floods resulting in a heavy impact on railways and other traffic. During the 1978 cyclone, there was a surge about 2.0m in Batticalloa and the sea had entered in to land for about 1.5km in Kalkuda area, thus resulting in partly submerged buildings. This included Meteorological building at Batticalloa.

Figure 2. Damaged houses in Chilaw, Sri Lanka due to gale force on 16th July 2009

## 3.0 PAST WIND ENGINEERING WORKS IN SRI LANKA

Since cyclones were not common hazard in Sri Lanka, special precautions for cyclone resistance were not generally observed in building design practice prior to the 1978 cyclone. Most of the damages in the buildings were probably caused due to poor quality building materials, tradition low wind resistant building technology and poor workmanship (Clarke *at el* 1979). However underestimates on wind load was an underlying reason for failure of the most buildings. Hence Government of Sri Lanka (GOSL) was embarked on developing an appropriate methodology for evaluate wind loads. Under this context, Australian Government sent a team of expertise to work together with both United Nations Development Programme team of consultants and the officers from Building Department, Sri Lanka. This exercise was mainly focused in two areas. One was to propose wind speeds and wind zones for Sri Lanka and the other was to propose an improved technology for build buildings for high wind conditions. According to this work, Sri Lanka was divided into three wind zones as shown in Figure 3. Another output of this was to propose two wind speeds that are named as wind speeds for post disaster structures and wind speed for normal structures as shown in Table 4.

The design manual named, “Design of Buildings for High Winds – Sri Lanka”, extensively covers the construction procedure of low rise buildings and the structural integrity of a building with regards to walls and roof. It also provides the guidelines for anchorage, bracing and continuity. The simple guidelines were developed for simple low rise buildings that can be adopted even today. Some of these simple techniques are shown in Table 5.


Figure 3. Wind zones in Sri Lanka

Table 4. Three second gust velocities used for different areas of Sri Lanka

| Wind Zone | Post disaster structures ($ms^{-1}$) | Normal structures ($ms^{-1}$) |
|---|---|---|
| Zone 1 | 54 | 49 |
| Zone 2 | 47 | 42 |
| Zone 3 | 38 | 33 |

Table 5. Techniques to improve resistance to high winds and cyclones

| Component of the building | Problem | Proposed Solution |
|---|---|---|
| Roof structure | Tie- down of rafter to top plate inadequate | Tie down rafter to top plate, bond beam or to foundations. |
| | Cantilever rafter breaks at eaves overhang | Restrict cantilevered section of rafter to 2’6”. If wider eaves are required use larger rafter specified. |
| | Tie down of rafter to ridge (or under – purlin) inadequate. | Tie down rafter to ridge and under purlin. |
| Roof sheeting | Roof sheeting lifts | Fix sheeting properly to reepers or purlins. |
| | Roof sheeting lifts at gable end | Fix sheeting properly using greater number of fixings required at gable end areas. |
| Walls | Ridge not tied down – (walls inadequately supported) | Form simple truss in roof by bolting ceiling joists or collar ties to rafters. |
| | Ridge not tie down (walls adequately supported) | Tie rafters together with straps or bolted timber. |
| | Tie- down bolts carried only part way down walls. | Tie down bolts must be carried right down into foundations and terminated in a CONCRETE footing. |

Numbers of Sri Lankan experts have carried out their research on wind engineering in recent past. Some research work has been based on wind speed that related to wind as energy source and some others were related to wind action on building. Zubair (1991) has carried some investigation on surface wind speeds in Hambantota area. According to his work, Hambantota has significant diurnal variation of wind speeds, especially in monsoon period, which is usual for Inter Tropical Convergence Zone. Wickramasooriya (1988) carried out a study to assess the feasibility of wind energy as an energy source for Sri Lanka. According to his work, Southern coastal region, Northern area and an also vast section of the dry zone (seasonally) are most promising for wind energy utilization. Some researchers were very keen about development of meteorology in Sri Lanka. Particularly Zubair (2002, 2004) highlighted the need of predictive capacity related to cyclone risks in Sri Lanka as an urgent. Because any research on climate conditions around Sri Lanka is of global and regional scientific importance given its equatorial location commanding the Indian Ocean.

According to a research done by Wijerathne and Jayasinghe in 1998 to determine suitable wind speeds for three wind zones and different structural behaviors of high rise buildings due to use of different structural types, it was suggested that the prevailing design wind speed of 33 $ms^{-1}$ for normal structures in wind zone 3 somewhat lower value than the wind speed that is been used by the countries with similar wind climate. Hence, instead of using 33 $ms^{-1}$ for designing high rise buildings, the recommended wind speed of 38 $ms^{-1}$ that is been use as the wind speed for post disaster structures in wind zone 3. It was also shown that the structural systems can improve the lateral stiffness considerably. According to his case study for the thirty storey building, use of coupled wall system, shear core system and out trigger reduced wind – induced acceleration by 25%, 27%, and 34%, respectively, with respect to the individual shear wall system. This may be a good example for Sri Lankan engineers to decide the type of structural systems that can use for high-rise buildings.

Since Sri Lanka do not have its own wind code, many designers and structural engineers in Sri Lanka use various codes and standards to design high-rise buildings. Hence, it is very difficult to compare wind calculations of various buildings, as different methods have been used. Also there are various thoughts about best suited wind code that can be used for Sri Lanka, until the development of a unique wind code to suite the Sri Lankan context. Wind speeds that were proposed for three wind zones do not have a sound statistical base. Therefore, it is necessary to propose new wind speeds and zoning system for Sri Lanka, based on a better statistical method.

There is another research project which provides answers for above questions. Premachandra (2008) carried out a research to determine new wind speeds for three wind zones and to compare the wind actions with respect to the three main wind standards on practice, i.e. Australian and New Zealand code AS/NZS 1170(2002) Structural Design Actions Part 2, BS 6399 – Part 2(1997) and National Building Code of India (2006) Part 6 Section 1 Clause 6 with those from CP3 Chapter V Part 2, which is the most extensively used wind code in Sri Lanka. The new wind speeds were calculated by using the available data in Meteorological Department of Sri Lanka. The new calculated wind speed value for Trincomalee in zone 1 is 75$ms^{-1}$ and wind speed value for Colombo in zone 3 is 30 $ms^{-1}$. These values are doubtful because of lack of availability of continuous gust wind speed data for the relevant areas. Hence Premachandra (2008) proposed to continue the wind speed proposed in wind design manual of 1978 until new winds speeds are derived from a proper data set. The various methods and the aspects were compared in this research, in finalizing an output to recommend the Australian and New Zealand code AS/NZS 1170(2002) Structural Design Actions Part 2 for Sri Lanka. The reasons behind those recommendations were the following. Australian code cover wide spectrum of wind including cyclones, it is used by many island nations like Fiji, Solomon Island, etc. and it gives higher reactions for buildings, thus making buildings much safer.

## 4.0 WIND ENGINEERING IN PRESENT

Prior to 2004 Indian Ocean Tsunami, that severely affected Sri Lanka, there was no proper mechanism to handle disaster situation. After the tsunami, Sri Lankan government has recognized this shortcoming and built a special mechanism to manage all kinds of natural disasters. As a result, on 13th of May 2005, the Disaster Management Center (DMC) was established under the National Council for Disaster Management (NDCM) (DMC Annual Report 2006). The main objectives of DMC are hazard mapping and risk assessment, information management, long – term risk mitigation, forecasting, early warning and information dissemination, preparedness to respond to disasters as it occur, emergency operation management and management of the post disaster activities after a disaster, etc. DMC has identified cyclone as one of the major hazards for Sri Lanka. Hence during a cyclone, tornado or high wind condition, DMC is responsible in issuing warning massages about impact and taking necessary response actions (Samarasinghe 2007). DMC also maintains a data base on many kinds of hazards with the collaboration of United Nations Development Programme (UNDP). This data base proved to be very useful in obtaining information about extreme wind conditions for more than past 30 years. DMC plays a major role in rehabilitation projects in Northern and Eastern provinces. It provides necessary assistance to improve the resistance of the buildings to disasters (hazards) by improving type plans, educating stakeholder, increasing risk awareness of public, etc. DMC is also providing funds to develop the knowledge base about wind engineering in Sri Lanka. Presently, there are two ongoing research projects at University of Moratuwa and University of Peradeniya and that are funded by the DMC.

One of it is to determine the basic wind speeds for various parts of the Island and propose an appropriate wind zoning system for Sri Lanka. Other research is to determine the suitability of various Wind standards that can be used in local conditions, until Sri Lanka develops its own wind loading standard. Under that particular research, Australian and New Zealand code AS/NZS 1170(2002) Structural Design Actions Part 2, Australian and New Zealand code AS/NZS 1170(1989) Structural Design Actions Part 2 BS 6399 – Part2 (1997) and Euro code BS EN 1991(2005) part 1-4 general actions – wind actions with those from CP3 Chapter V Part 2 which is current practice in Sri Lanka are used to evaluate wind actions on buildings of different heights such as 48m to183m, etc. The wind actions will be evaluated by the means of forces in structural elements at the ultimate limit state with three dimensional models created using SAP 2000 software as well as the accelerations at serviceability limit state. The result of this research can be utilized as an interim guide lines for designing building for wind loads until a publication arises to address the needs of Sri Lanka wind standard.

## 5.0 FUTURE WIND ENGINEERING PROJECTS

Disaster Management Centre takes a major role in rehabilitation works in Northern and Eastern province in Sri Lanka. DMC promotes the construction of buildings with great degrees of hazard resilient constructions especially for school buildings, hospital buildings and community centers. Since cyclone is one of the common hazard for these areas, DMC gives special attention to design and build these buildings with more resistant to cyclones. In order to achieve this, DMC has been preparing a check list which can be easily followed by general public and local authorities also improving type plans for grater cyclone resistance.

GOSL has taken a strategically important decision to produce ten percent of its electricity from renewable energy sources by 2015 (www. srilanka.usaid.gov, 2008). Wind may be a one of best option for that because Sri Lanka is blessed with vast wind energy resource. This can be used to strengthen Sri Lanka's energy security and diversify its energy supply options. Thus in 2006, the Ceylon Electricity Board (CEB) signed Letters of Intent with four commercial developers for the purpose of building plants to produce 34 Megawatts of wind power on the western coast of Sri Lanka. The proposed wind plants with installed capacity of 34 megawatts would produce about 1 percent of total power generation in Sri Lanka. Thus, though wind may offer certain challenges to the design and construction of built environment, it can also become a blessing in disguise if properly harnessed.

## 6.0 CONCLUSIONS

Sri Lanka is vulnerable to tropical cyclone due to its geometry and geographical location. After the 1978 massive cyclone, a design manual was developed to address the construction of low rise building but it is applied for high rise building construction practices as well. Thus, it is mandatory to develop new strategies in wind engineering that is suitable for the Sri Lankan context. Wind zones and their wind speeds should be revised it necessary because the derivation of present wind speeds was not based on sound theoretical basis and adequate statistical data. GOSL is now keen on building more cyclone resistant buildings especially in the areas of possible cyclone hazards especially with public buildings while promoting better practice for privately built structures using a check list. DMC also plays a key role in developing wind engineering practices in Sri Lanka by maintaining a good data base, developing type plans and increasing public awareness about severe wind conditions. GOSL is also keen to producing electricity from wind energy in future because many coastal parts of the island are rich with ample wind resource.

## ACKNOWLEDGEMENT

Authors of this paper thank to Disaster Management Centre of Sri Lanka for its valuable assistance to produce this paper.

## REFERENCES

1. Clarke, A.G, Swane, R.A, Schneider, L.M, Shaw, P.J.R, *Technical assistance to Sri Lanka on Cyclone Resistant Construction*, Vol 1, Part 1 -4, 1979, pp 2/1-2/5
2. *Cyclone Events 1900 – 2000*, Available Source, www. meteo.gov.lk, 2009
3. Data base for natural hazard in region Sri Lanka, www.desinventar.lk , 2009
4. Disaster Management Center, Sri Lanka, *Annual Report 2006*, Available source www.dmc.gov.lk,2009
5. Ministry of Local Government , Housing and Construction, Sri Lanka, *Design of Buildings for Higher Wind- Sri Lanka*, 1980, pp 7/9 – 7/21
6. Premachandra, W.R.N.R., *Study of New Wind Loading Code to be Adopted in Sri Lanka*, M.Sc Thesis, Graduate School, Kasetsart University, Thailand, 2008
7. Samarasinghe, G.B, *Role of Sri Lanka Meteorological Service in Disaster Risk Reduction,2007* Available Source, http://www.wmo.int/pages/prog/rp/documents/5-4-SiriLanka-Samarasinghe.pdf , 2009
8. Wickramasooriya, S.S., Indiketiya, A.V., Jayasiri S.R., Sumanasiri D., *Some Observations on the use of wind energy in Sri Lanka*, Engineer, Journal of Institution of Engineers, Sri Lanka , Vol: XVI, No: 2, June 1988, pp 13-21
9. Wijeratne, M.D., Jayasinghe, M.T.R., *Wind loads for high-rise buildings constructed in Sri Lanka*, Transactions Part 2- Institution of Engineers, Sri Lanka, 1998, pp 58-69
10. *Wind Power - A Sustainable Response to the Energy Crisis in Sri Lanka,* www. srilanka.usaid.gov/action_detail.php?action_id=109, 2009
11. Zubair, L., *Development of Meterology in Sri Lanka*, Engineer, Journal of Institution of Engineers, Sri Lanka , Vol: XXXV, No: 2, May 2002, pp 14-18.
12. Zubair, L., *Towards Developing Weather and Climate Prediction for Sri Lanka*, Engineer, Journal of Institution of Engineers, Sri Lanka , Vol: XXXVII, No: 2, September 2004, pp 53-58.
13. Zubair, L., *Variation of surface winds at Hambantota from April 1990 to March 1991*, Journal of National Science Council Sri Lanka, 1998, 26(3), pp 235 – 245.