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Comparative Study on R.C.C. Multistoried Building Subjected To Is: 875 (Part 3) Wind Loads Vs Hud-Hud Cyclone Wind Loads

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***Abstract**:*

Indian Standard IS: 875 (Part 3)-1987 deals with wind load on buildings and other types of structures, it is under revision and draft code is also published by Bureau of Indian Standards. The recent Hud-Hud super cyclone occurred at Vishakhapatnam had a recorded wind speed of 77.5 m/s (279 kmph) as recorded by Indian Metrological Department, Visakhapatnam. Whereas the present code contemplates only a basic wind speed of 50 m/s (180 kmph) for this region. As per the observations of present cyclone, suggested wind speeds are no longer on conservative side for the safety and stability of the structures built as per the code. It is observed that a variation of 55% is observed in basic wind speed during Hud-Hud super cyclone for Vishakhapatnam region. Lot of medium to high rise buildings were designed and constructed with reference to this code. The structures which are actually designed and constructed for 180 kmph wind were subjected to a wind speed of 279 kmph. Collapse and/or damage to the structures especially to the trusses, poles, hoardings, compound walls, industrial structures and buildings were observed during Hud-Hud cyclone.

There is an encroachment into factor of safety limits of the already designed structures. The foundation behavior and stress states are also different under increased wind loads. Hence, it is appropriate to study the available factor of safeties under the increase wind load along with other load combinations. In this paper a comparative study is made to find the effects of increased wind load due to present cyclone on a R.C.C multi-storied building compared to IS: 875 (Part 3) wind loads. STAAD. Pro finite element software is used for analyzing the structure. From STAAD.PRO software analysis results are sorted out for bending moments, axial forces in ultimate bay and penultimate bay columns at footing level and stilt floor level, which are generally critical for design. Stilt floor bending moments and shear forces in beams are compared. Inter storey drift and maximum sway of the transverse frame is also compared. The effects of various forces are studied and reported in this work.

Keywords

*Indian Standard IS: 875 (Part 3)-1987, Indian Metrological Department, **Hud-Hud cyclone***

1. Introduction

A building has to perform many functions satisfactorily. Amongst these functions are the utility of the building for the intended use and occupancy, structural safety, fire safety and compliance with hygienic, sanitation, ventilation and daylight standards. The design of building is dependent upon the minimum requirements prescribed for each of the above functions. The minimum requirements pertaining to the structural safety of buildings are being covered in loading codes by way of laying down minimum design loads which have to be assumed for dead loads, imposed loads, wind loads and other external loads, the structure would be required to bear. Strict conformity to loading standards, it is hoped, will not only ensure the structural safety of the buildings and structures which are being designed and constructed in the country and thereby reduce the hazards to life and property caused by unsafe structures, but also eliminates the wastage caused by assuming unnecessarily heavy loadings without proper assessment.

1.2. Hud-Hud Cyclone

Very severe cyclone 'HUD-HUD' struck, Andhra Pradesh coast at Vishakhapatnam on 12th October, 2014. It was one of the first episodes in the recent history that cyclone of such intensity landed on an urban city leading to high degree of devastation. This very severe cyclonic storm developed from a low pressure area which lay over tenasserium coast and adjoining North Andaman Sea in the morning of 6th October, 2014, concentrated into a depression in the morning of the 7th October, 2014. Over the

North Andaman Sea; then moving West-northwest wards to intensify into a cyclonic storm in the morning of 8th October, 2014 which crossed Andaman Islands close to Long Island between 0830 and 09-30 hours IST on 8th October, 2014. It then emerged into Southeast Bay of Bengal and continued to move West-North westwards. It intensified into a severe cyclonic storm in the morning of 9th October, 2014 and further into a very severe cyclonic storm in the afternoon of 10th October, 2014. It continued to intensify while moving northwest wards and reached maximum intensity in the early morning of 12th October, 2014 with a maximum sustained wind speed of 180 kmph over the west central Bay of Bengal, off Andhra Pradesh coast

S.A.Raji and A.O.Ibrahim (March 2016), has investigated the effect of wind load on multi-storey building. A Finite element modelling and analysis on an example problem is performed in Staad.Pro software to study the effect of wind on multi-storey building. The deflections, shear forces and bending moments of the structure were determined. The study revealed that the first floor had lowest wind load of 112 N/m2 while the last floor (roof) had the highest value of 272 N/m2 with displacement, shear force and bending moment value of (0.0086 m) and 103.2445 kN and 191 kN-m respectively. Conclusively, the average wind speed, dynamic wind pressure, wind force, displacements (0.0013 m to 0.0086 m) increases and shear forces (1023.2343 kN to 103.2445 kN) decreases while the overturning moment (191 kNm to 123 kNm) decreases with increase in height. This implies that at greater heights, structures are more susceptible to wind loads. Thus, wind has a greater effect on tall building.

Ming GU (2009), Consideration of multi-mode contributions and their coupling effects are presented. Wind forces acting on the buildings were then computed based on the wind pressures. The wind force characteristics, including wind force coefficient, PSD, coherence function and so on, were analyzed in detail.

Mark Caulfield, Trevor Dunne, Peter Gill, John Perron (April 2012), Over the last several decades the intensity and number of extreme wind storms, like tornadoes and hurricanes, has escalated at an alarming rate. Consequently, there has been an increase in damage to homes exposed to these storms. Therefore, the primary intent of this MQP was to identify methods and approaches to affordably and effectively improve residential home design and construction. From the information our team gathered through research, interviews, and experimentation, we designed an affordable structure capable of withstanding 110 mph 3 second wind gusts.

2. Details regarding present HUD-HUD cyclone

2.1 Impact of HUD-HUD Cyclone

As per IMD reports, based on INSAT-3D satellite imageries, a low level circulation developed over Tenasserium coast in the morning of 6th Oct. 2014 was intensified day by day and became as a VSCS-Hud-Hud, crossed at 17.9°N/83.2°E of Visakhapatnam coast, Andhra Pradesh, India between 1200 and 1300 hrs IST of 12th October 2014. Wind speeds during different timing was recorded as 74 knots and 69 knots with in a span of 3 minutes. According to interpretation of satellite imageries, as per Dvorak technique by the IMD, the Hud-Hud cyclone intensity was T5.0 on intensity scale which corresponds to an MSW of about 90-100 knots (167-185 kmph). The DWR, VSK recorded 67 meters per second or 130 knots (241kmph) at a height of about 200 meters. The one second peak gust wind speed was 140.6 knots (260 kmph) at 10:42 hours IST at Visakhapatnam.

2.2 Major Impact in Visakhapatnam and its surrounding areas:

- Loss of life, shelter
- Damage to environment
- Damage to power and water supply
- Failure of communication network
- Damage to infrastructure and industries
- Disturbance to transportation
- Strom Surge
- Inundation of low laying areas
- Crop Damage
- Loss of fishing boats
- Disturbance to livelihood

The following figures shows the satellite image of cyclone eye, damage occurred at various major places due to HUD-HUD cyclone:

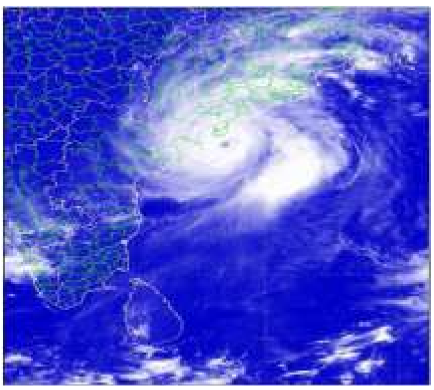

Fig.2.1 Satellite image showing the cyclone eye of Hud-Hud

Fig.2.2 Complete damage to Hindustan Ship Yard subjected to Hud-Hud super cyclone

Fig.2.3 Photo showing damages to roof truss at Vizag Air Port subjected to Hud-Hud cyclone

3. Analysis of r.c.c multi-storied building

A typical six-storied building with ordinary moment resisting frames and regular in plan was studied, the relevant data of the building is summarized in Table 1. The building had an open ground storey (stilt floor) for parking purpose, with exterior infill walls only in the upper stories. The height of the ground storey was 3.15 m. The dimensions of the members were selected based on the design for gravity loads.

A computational model was developed using STAAD.Pro (Fig.3.1). Staad.Pro model is prepared for the building structure with base of the columns as fixed. Loading from different floors is applied on the staad model prepared for the structure. Primary load cases considered are dead load, live load and wind load. The beams and columns were modeled using 1D frame elements, with the respective section properties and modulus of concrete. The boundary condition of the base columns from the isolated footing was modeled as fixed supports at the top of the footing. The slabs and exterior infill walls were not modeled explicitly. Their weights and the slab, live loads were assigned on the supporting beams. The high in-plane stiffness of the slab at slab levels was not taken into account.

The structure is analyzed for dead load, live load, and wind load. The structure is modeled as a 3-dimensional space frame structure depicting all the floors including grade beams. The calculations of the wind pressures at different levels of the building are shown in Table 3.1 and 3.2 respectively. The lateral forces at each floor levels were applied at the beam column nodal points automatically by STAAD.Pro software. The member forces were combined with those from the analysis for gravity loads.

The original model and its variants were designated as follows.

1. Reference building is subjected to a basic wind speed, v_b of 50 m/s.
2. Reference building with same geometry, member properties, same gravity loading but only variant is with a wind speed (Hudh-Hudh cyclone), v_b of 77.5 m/s (279 kmhp).
3. The floor plans, geometry of two models are similar

3.1 Loading

Case I: As per IS: 875 (Part 3) is considered
Class B, Category 3 Structure
Basic wind speed, v_b = 50 m/s

Table 3.1 Wind loading as per IS: 875 (Part 3)

Height (m)	k_1	k_2	k_3	$V_z = v_b k_1 k_2 k_3$ (m/s)	$p_z = 0.6 v_z^2$ (N/m^2)
Up to 10	1.0	0.88	1.0	44	1.162
10 to 15	1.0	0.94	1.0	47	1.325
15 to 20	1.0	0.98	1.0	49	1.441
20 to 30	1.0	1.03	1.0	51.5	1.591

Case II: As per Hud-Hud cyclone wind speed of 279 kmph (77.5 m/s) recorded and reported by Indian Metrological Department, Visakhapatnam is considered
Class B and Terrain Category 3 structure
Basic wind speed, v_b = 77.5 m/s

Table 3.2 Wind loading as per Hudh-Hudh cyclone

Height (m)	k_1	k_2	k_3	$V_z = V_b k_1 k_2 k_3$ (m/s)	$p_z = 0.6 v_z^2$ (N/m^2)
Up to 10	1.0	0.88	1.0	68.20	2.791
10 to 15	1.0	0.94	1.0	72.85	3.184
15 to 20	1.0	0.98	1.0	75.95	3.461
20 to 30	1.0	1.03	1.0	79.83	3.823

3.2 Comparison parameters.

1. Comparison of axial forces, bending moment forces in columns for the two cases. Comparison of bending moment and shear forces in beams for the

two cases and support reactions are also compared for the two cases.

2. Total sway of the building.
3. Inter storey drift

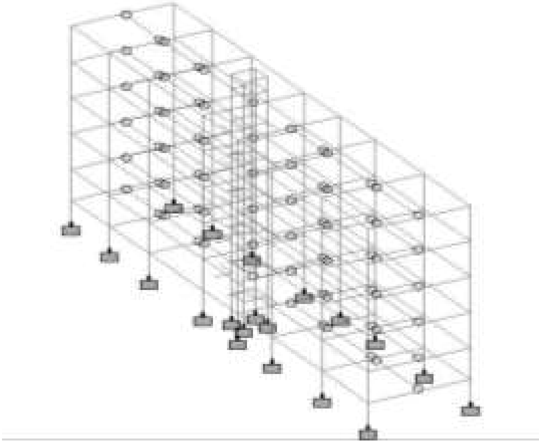

Fig.3.1 STAAD.Pro 3D geometrical model used in analysis

4. Results and discussions

The presented results are limited to the values of axial forces and bending moments in the base columns (footing level) and stilt floor columns, shear forces and bending moments in beams in ground floor slab level due to wind loads in transverse +ve X-direction and load combination of DL+LL+WL in +ve X-direction which is the critical direction. The reason for selecting for comparison of WLX alone is to observe the variation of wind loading under IS: 875 (Part 3)-1987 w.r.t HUD-HUD cyclonic wind loads. Generally DL+LL+WLX is the governing wind forces for design of structural elements viz., beams and columns in a R.C.C building structure hence this load combination is selected for compassion of analysis results. These values are compared for ultimate and penultimate bay frames. The values of supporting reactions, maximum sway of the transverse frame at top most node i.e., roof slab level are also compared. The bar chart compares the forces for the columns/beams in each case with the columns of the reference case (Case 1).

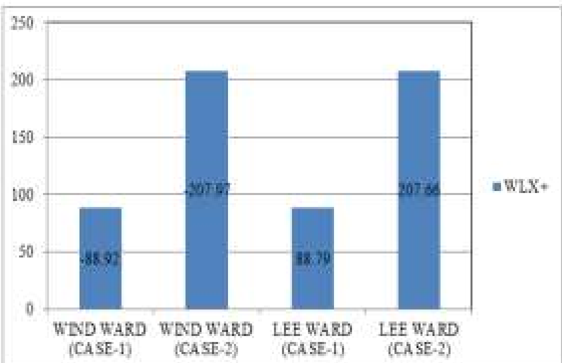

Figure 4.1.1 Support reactions at footing node level for exterior columns in penultimate bay for WLX+ primary load

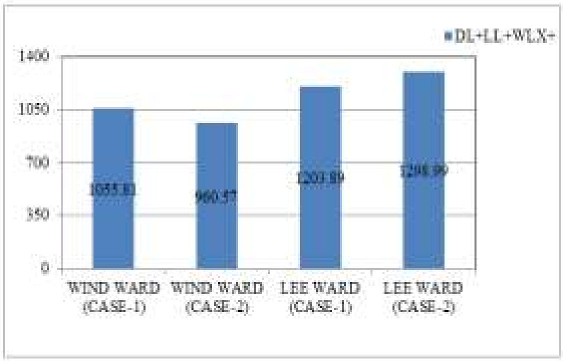

Figure 4.1.2 Support reactions at footing node level for exterior columns in penultimate bay for DL+LL+WLX+ load combination.

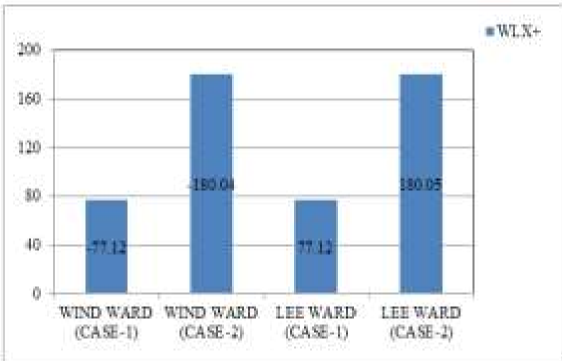

Figure 4.2.1 Support reactions at footing node level for exterior columns in ultimate bay for WLX+ primary load.

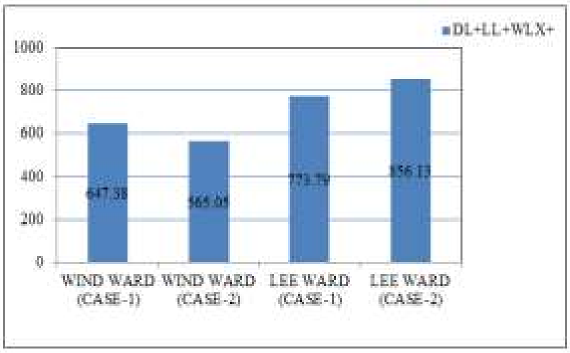

Figure 4.2.2 Support reactions at footing node level for exterior columns in ultimate bay for DL+LL+WLX+ load combination.

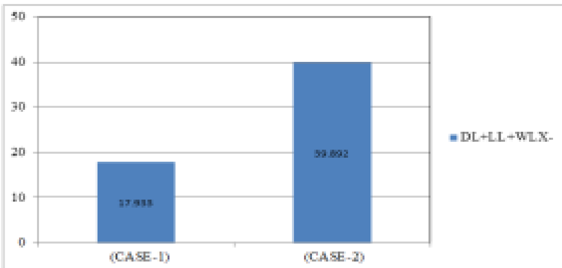

Figure 4.3 Maximum sway of transverse frame at building roof slab level

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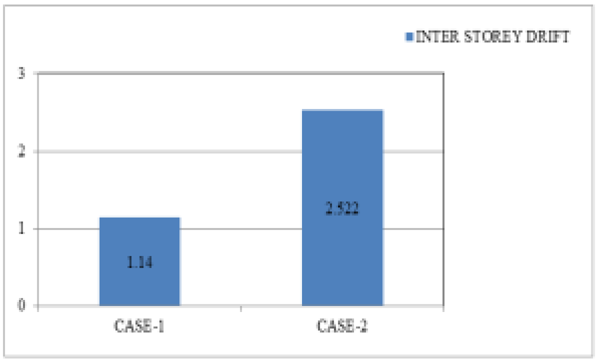

Figure 4.4 Inter storey drift of transverse frame

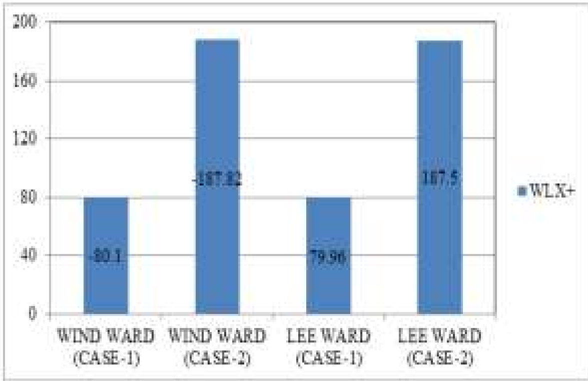

Figure 4.5.1 Axial forces in columns at stilt floor level for penultimate bay for WLX+ primary load.

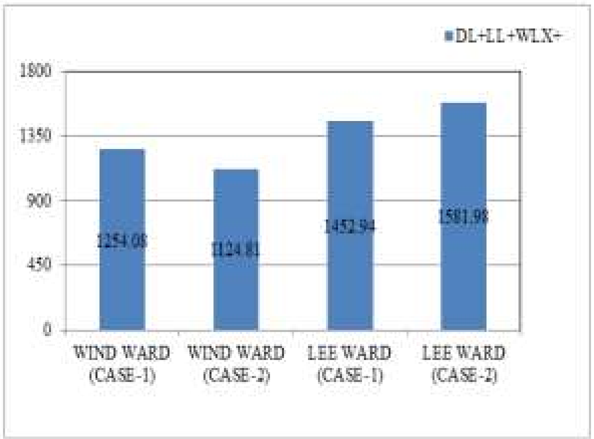

Figure 4.5.2 Axial forces in columns at stilt floor level for penultimate bay for DL+LL+WLX+ load combination.

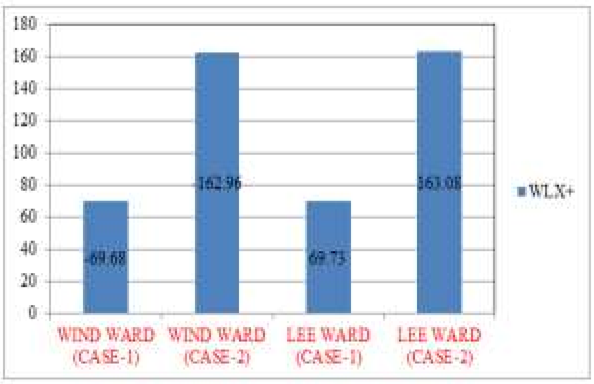

Figure 4.6.1 Axial forces in columns at stilt floor level for ultimate bay for WLX+ primary load.

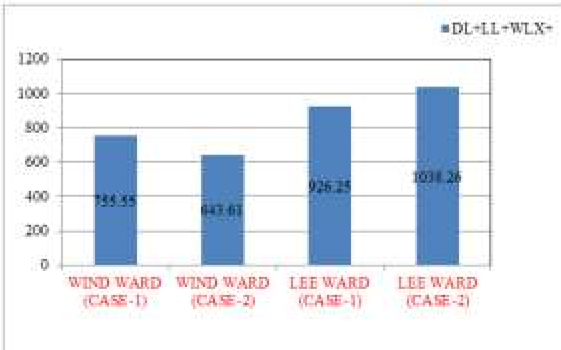

Figure 4.6.2 Axial forces in columns at stilt floor level for ultimate bay for DL+LL+WLX+ load combination.

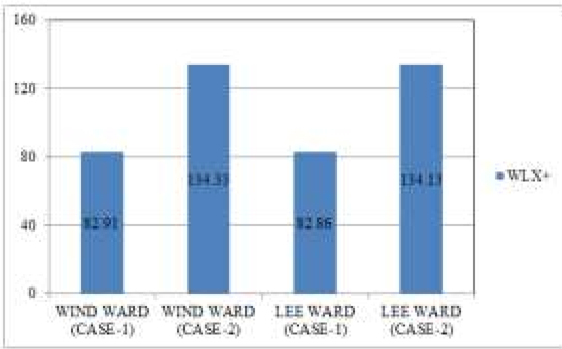

Figure 4.7.1 Bending moments in footing level exterior columns is penultimate bay for WLX+ primary wind load.

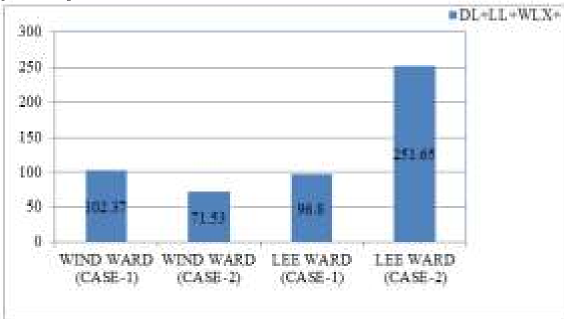

Figure 4.7.2 Bending moments in footing level exterior columns is penultimate bay for DL+LL+WLX+ load combination

5. Conclusions

The following conclusions can be drawn from the analysis of two models under wind loading of Case 1 and Case 2.

The increase in wind loads from IS: 875 A(part 3) code specified wind load to HUD-HUD cyclone wind load has increased the sway of the building and inter storey drift at roof top level, but such increase is well within permissible limits as specified in clause of IS: 456-2000.

The support reaction at footing top node levels has only 8% variation in terms of axial forces under Case 1 and Case 2 loadings when under DL+LL+WLX+ load combination which is the critical load combination for foundation proportionating and structural design. The 8% variation in axial force will not affect the safety of the foundations.

Generally in any building the axial forces in stilt floor columns are higher, which governs the structural design of columns in terms of sizing and percentage of reinforcement. There is a 9% variation in axial forces for the Case 2 loading visa vis for Case 1 loading under the load combination consideration of DL+LL+WLX+. Thus the safety of the columns will not be effected even when the wind load is changed to HUD-HUD cyclone (279 kmph) from IS: 875 (Part 3) specified wind speed (180 kmph).

The variation in bending moment is significant, which is equal to 30% for exterior columns of penultimate bay for Case 2 loading when compared to Case 1 loading under DL+LL+WLX+ load combination. Even though 30% variation in bending moment is significant, columns found to be safe, since factor of safety available against loads in limit state of collapse is 50%. The increase in shear and moment can lead to a brittle failure of the columns if collapse took place, as the available ductility can be less in presence of high axial loads.

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The success and final outcome of this paper required a lot of guidance and assistance from so many people and I am extremely fortunate to have got this all along with the completion of my paper work. We express our sincere & great thanks to the Department of Civil engineering; Institute of Engineering and Technology, Sitapur Road, Lucknow, India and Motilal Nehru Institute of Technology, Allahabad, India, for their valuable guidance and timely help during the study.

7. References

1. IS: 456-2000 Plain and Reinforced Concrete Code of Practice (Fourth Revision).

2. IS: 875 Part I-1987, Code of Practice for Design Loads (Other than Earthquakes) for Buildings & Structures, Part 1 - Dead Loads.

3. IS: 875 Part II-1987, Code of Practice for Design Loads (Other than Earthquakes) for Buildings & Structures, Part II - Imposed Loads.

4. IS: 875 Part III-1987, Code of Practice for Design Loads (Other than Earthquakes) for Buildings & Structures, Part III - Wind Loads.

5. IS: 1080-1985, Code of Practice for Design and Construction of Shallow

Foundations.

6. IS: 1786-1985, specification for high strength deformed steel bars and wires for Concrete Reinforcement.

7. IS: 1893-1984, Criteria for Earthquake Resistant Design of Structures.

8. IS: 1893 (Part I)-2002, Code of Practice for Earthquake Resistant Design of Structures-General Provisions and Buildings.

9. IS: 1904-1986, Design and Construction of Foundation in Soils Code of Practice' (First Revision) (Amendment 1).

10. IS: 2911 (Part 1 to 4)-1985, Code of Practice for Design and Construction of Pile Foundations.

11. IS: 4326-1993, Code of Practice for Earthquake Resistant Design and Construction of Buildings.

12. IS: 8009 (Part 1)-1976, Code of Practice Calculation of Settlement of Foundations: Shallow Foundation Subject to Symmetrical Static Vertical Loads (Amendment 2).

13. IS: 13920-1993, Ductile Detailing of Reinforced Concrete Structures.

14. Das, B.M (2000), Principles of Foundation, PWS-KENT Publishing Company, Second Edition, Boston.

15. Dayaratnam, P, (2003), Design of Steel Structures, S.Chand & Company Limited, Second Edition, New Delhi.

16. Arya. A.S., and Ajmani, J.L., (2007), Design of Steel Structures, Nem Chand & Brothers, Fifth Edition, Roorkee.

17. Varghese, P.C., (2005), Foundation Engineering, Prentice-Hall of India Private Limited, First Edition, New Delhi.

18. Varghese, P.C., (2002), Limit State Design of Reinforced Concrete, Prentice-Hall of India Private Limited, Second Edition, New Delhi.

19. Vazrani and Ratwani (1996), Structural Analysis, Khanna Publishers, Second Edition, New Delhi.

20. Salmon E.H., 1945. Materials and Structures, Vol. 1, Longmans, Green & Co., London, UK. Salmon E.H., 1948. Materials and Structures, Vol. 2, Longmans, Green & Co., London, UK. Seward, D., 2009. Understanding Structures: Analysis, Materials, Design, 4th Revised Edition, Palgrave Macmillan, Basingstoke, U.K.

21. Spofford, C.M., 1939. The Theory of Structures, McGraw-Hill, New York, U.S.A.

22. Timoshenko, S.P. and Gere, J.M., 1961. Theory of Elastic Stability; McGraw-Hill Kogakusha, Tokyo, Japan.