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Comparative Analysis of Lateral Forces and Development of Steel Coefficient For Different Earthquake Zones & Wind Speeds in India

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Abstract—A tall building construction involves huge amount of money. The design of the building depends upon various parameters that include building usage, loading, site conditions, soil conditions, climatic conditions & site topography etc.Analyzing each factor is necessary to have an optimum design as fluctuations from the actual conditions may impact the safety of structure and at the same time it can be cost intense. As the tall buildings are more prone to sway than the low-rise buildings thus the impact of wind and seismic forces acting on them becomes critical to analyze. In this research paper a building is modelled for earthquake resistant design and wind resistant design using conventional bricks and AAC Blocks and the base shear reactions are compared for both the cases. After that the loading is considered and analyzed whether various members such as beam, slab and shear walls are governing to wind load or the earthquake load on different storeys and based on this the steel reinforcement coefficient of corner & side beam and shear wall is prepared for each seismic and wind resistant zone. This will help us to see the variation in each zone and to design the building accordingly. This micro level designing will improve the structural system of the building and its dynamic response. The findings of this research will help us to understand the governing load in building and to take sufficient action in designing. Further this technical information about the structural response of the building would be very useful for designers.

Keywords: Tall Buildings, seismic and wind loads, Reinforcement, ETABS, load combinations

I. INTRODUCTION

In India Housing industry is one of the leading economy generating industry as it caters to the need of growing Indian population which migrates to the cities. The key factors for the increasing demand in building spaces are Rapid urbanization, Rise in the number of nuclear families, Easy availability of finance, Repatriation of NRIs and HNIs, Rise in disposable income and Growth in population (Real Estate, 2017). The lack of spaces in urban areas, high land cost & Government policies are the few major reasons that the tier I cities of India are rapidly shifting from low rise structures to the tall buildings. The world's first skyscraper was built in Chicago in 1885 and was just only 42 m in height. In India a building of height greater than 45m, but less than 250m is called a tall building (CRITERIA FOR STRUCTURAL SAFETY OF TALL BUILDINGS, 2016). Tall buildings demand construction methods that meet tight budgets and construction programs, are flexible in planning and use. Wind and earthquake comparative analysis is important to understand about the building parameters and it will help to understand that building is governing to earthquake resistant or wind resistant. Tall Buildings i.e. 40 storey building is important to understand that top storey members such as beam, slab and shear walls are governing to wind load or the earthquake load to understand the governing load in building to take sufficient action in designing. Base shear reactions in 40 storey building changes by changing the use of AAC Block in place of conventional brick. It will also help to understand how much the base shear has been reduced in building. AAC block has various merits like it is light in weight and therefore it reduces the total base shear of the building which may help to make building light and it will create the comfort for human living in the building making comparatively less sway of top floors of the building.

II. RESEARCH METHEDOLOGY

To achieve the objective a building is modelled on Etabs 2016 which is based on a real building. For earthquake resistant design of building, since the building taken for study is having a height of 136 m which is more than 40m, the dynamic analysis is performed as per Indian Standard Code (Part 1 – General Provisions For All Structures And Specific Provisions For Buildings, 2005). The dynamic analysis is performed using response spectrum method and the building is checked for modal participation factors, different considered modes and for the torsion also. For wind resistant design of building, the effect of wind on the structure is determined by the combined action of external and internal pressures acting upon it. In all cases, the calculated wind loads act normal to the surface to which they apply. wind speed in the atmospheric boundary layer increases with height from zero at ground level to a maximum at a height called the gradient height. There is usually a slight change in direction (Ekman effect) but this is ignored in the is code (PArt 3 - Wind Load, 1987).The gust factor for all terrain categoriesarefound outthrough which the forces for each terrain category and for each wind speed is calculated. The forces further to be used to analyzed the building to calculate the steel reinforcement coefficient for beam and shear wall. Buildings is also designed with due attention to the effects of wind on the comfort of people inside and outside the buildings.From these four combinations a comparative study is done between the base shear values. Then the same 40 storey RCC residential building is analyzed in seismic zone II, III, IV and V with the all wind speed 33m/sec, 39m/sec, 44m/sec, 47m/sec, 50m/sec, 55m/sec and the steel reinforcement in Kilogram(KG) is calculated. And at the last the steel coefficient of corner & side beam and shear wall is found out by dividing the quantity (KG) of reinforcement by the plan area, which is represented through graphs.

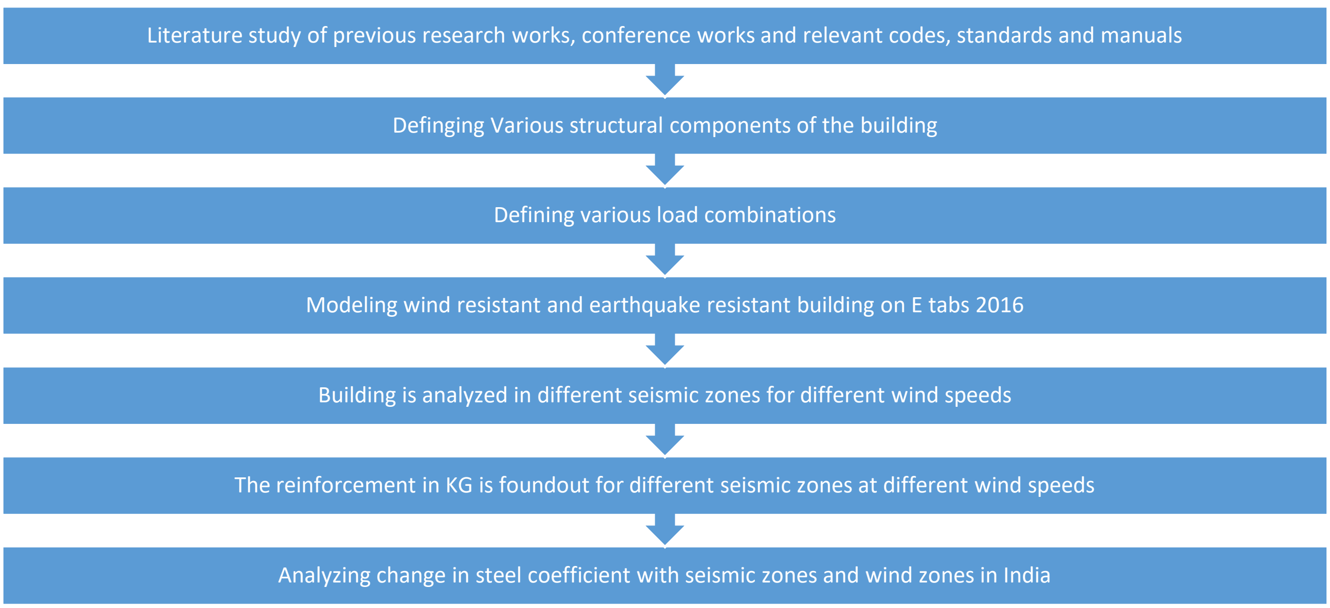

Fig.1 Depicting the broad research methodology

III. LITERATURE REVIEW& CODAL PROVISIONS

In a research done in 2009 on model of27 tall buildings and after various regression analysis a new concept called modified SRSS method was coined, while the researcher in its concluding remarks says that there may be more problems related to wind analysis which may be sorted out in future (Gu, November 8-12, 2009). A research was done in 2011 taking a 51 m tall multistoried building in which the variation in design wind speed with height&the variation in design wind pressure with height is calculated using Indian standard 875 (part 3) -1987 with the help of MS-Excel(N G Shilu, 2011). A research was done in 2014 taking a high rise building of 183 m height and evaluating the wind forces using five different major wind codes and standards and it is found that base shear and base moments that governs distribution of the wind load values along the height of the building are not same when calculated using different codes (A. U. Weerasuriya, 2014). In a study done in 2016 various facts are found out that includes increase of dynamic wind load with height, linear increase of wind forces for a particular wind speed of 47 m/s which remains constant for initial 3 storeys & the dependency of soft storey effect with its location in the structure (Ashwini S Gudur, 2016).

IV. STRUCTURAL MODELING OF BUILDING

A 40-storey building for a residential tower is modelled based on a real project, the building is assumed to be in Delhi (seismic zone of IV India) on a site having medium soil. Design for seismic load is done as per IS: 1893 Part 1: 2002.

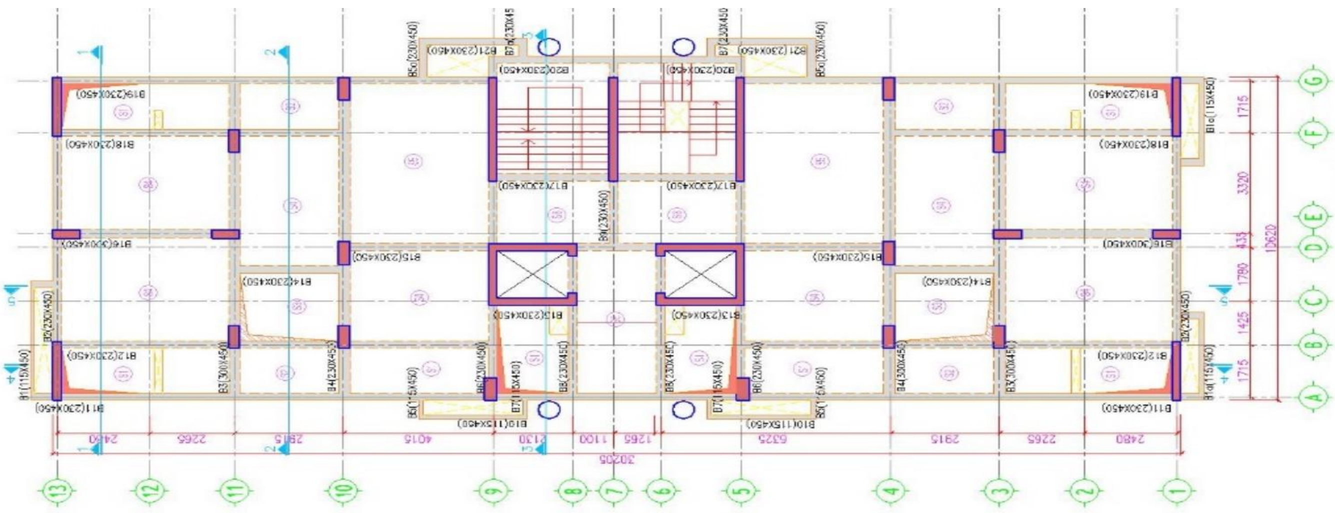

Fig.2Ground floor framing plan

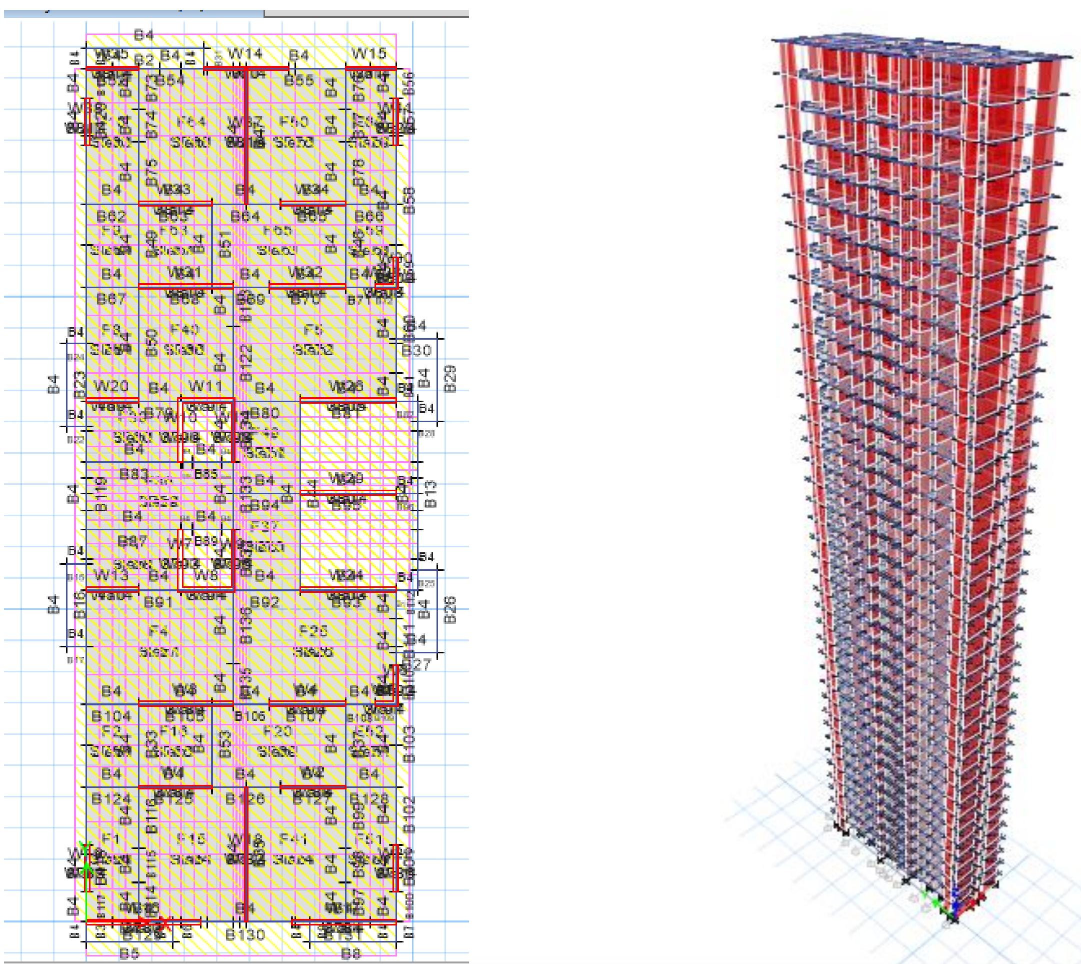

Fig.3Modelled building using ETABS 2016

The above figure shows the ground floor plan of the building, the following assumptions are made while modelling the building.

1. The case study building consisting of G+39 storey. Only the superstructure of case study building to be designed. The analysis and design of the case study building is to be performed using E- tabs 2016.
2. The building is residential tower and using external walls 230mm of width and 115 mm internal wall with the 12-mm plaster at both sides.
3. The floor Diaphragm are assumed to be rigid.
4. Dynamic Analysis to be performed using response spectrum method.
5. All dimensions are in m, unless otherwise specified.

The Following are the member sizes and properties adopted after the designing.

TABLE 1

BUILDING AND LOAD DESCRIPTION

Modelling details of building	
Plan dimension	10.87m X 30.24m
No. of storeys	Ground + 39 storeys
Building frame system	Special Moment Resisting Frame
Ground storey height	3.4 m
Typical storey height	3.4 m
Building use	Residential
Foundation type	Fixed
Seismic Zone	Analyzed for Zone –II, III, IV& V
Soil Type	Medium soil
Importance Factor (I)	1
Response Reduction Factor (R)	4
Damping Ratio	5 %
Time period in X direction	0.027 sec {Clause 7.6.2 of IS:1893(Part 1): 2002}
Time period in Y direction	0.016 sec {Clause 7.6.2 of IS:1893(Part 1): 2002}
Base seismic coefficient Sa/g in X direction	1.405
Base seismic coefficient Sa/g in Y direction	1.245
Design horizontal seismic coefficient in X direction	0.24
Design horizontal seismic coefficient in Y direction	0.24
Material Properties	
Grade of steel for longitudinal/main reinforcement	Fe500
Grade of steel for shear/ties reinforcement	Fe415
Grade of concrete and its Young's Modulus (E)	
Columns	M25 – 25 x 10^6 KN/m^2
Shear Walls	M50 – 25 x 10^6 KN/m^2
Beam/Slab	M30 – 25 x 10^6 KN/m^2
Density of concrete	25 KN/m^3
Poisson's ratio (of concrete)	0.20
Structural members	
Slab Thickness	200 mm
Wall thickness	115 and 230 mm thick

Shear wall thickness	
Wall 1 (0-10)	400 mm
Wall 2 (11-20)	300 mm
Wall 3 (21-30)	200 mm
Wall 4 (31-40)	150 mm
Beam sizes	
Floors 1 to 10	0.4 x 0.6 m
Floors 11 to 20	0.3 x 0.6 m
Floors 21 to 30	0.3 x 0.45 m
Floors 31 to 40	0.3 x 0.3 m
Column sizes	
Floors 1 to 15	1.2 m x 0.80 m
Floors 16 to 25	1.0 m x 0.80 m
Floors 26 to 40	0.8 m x 0.80 m
Dead Load Intensities	
Wall 230 mm thick	13.5 KN/m
Wall 115 mm thick	7.5 KN/m
Parapet Wall load	5.61 KN/m
Railing Load	3.0 KN/m
Floor finish and plaster on ceiling	1.45 KN/m^2
Brick coba and plaster on ceiling	2.75 KN/m^2
Sunk load (450 mm sunk)	4.05 KN/m^2
Staircase loading	9.2 KN/m^2
Unit Weight Taken	
Bricks with lime sand	20.40 KN/m^3
Cement Mortar	20.40 KN/m^3
Cement Plaster	20.40 KN/m^3
Tiles	0.02 – 0.03 KN/m^3
Flooring (Thickness 10mm)	0.22 KN/m^3
Autoclaved Reinforced cellular concrete	8.35 – 9.80 KN/m^3
Dead Load Intensities	
outer beam is of 230 mm wall with 12 mm plaster at both side	19.27 KN/m
inner side of wall 115 mm with 12 mm plaster at both side	11.3 KN/m
terrace (at periphery)	7.93 KN/M
terrace (at shaft)	3.19 KN/M
Live Load Intensities	
Living room, Kitchen, Toilet	2 KN/m^2
Corridor, Staircase, Lobbies, Balcony	3 KN/m^2
Terrace (Accessible)	2.0 KN/m^2
Terrace (Non- Accessible)	1.5 KN/m^2
Parking	5 KN/m^2

V. RESULTS

A. Outcomes in Terms of Reinforcement Coefficient of Beams

For combination of: Seismic Zone II- wind speed 33m/sec, 39m/sec, 44m/sec, 47m/sec, 50m/sec, 55m/sec.

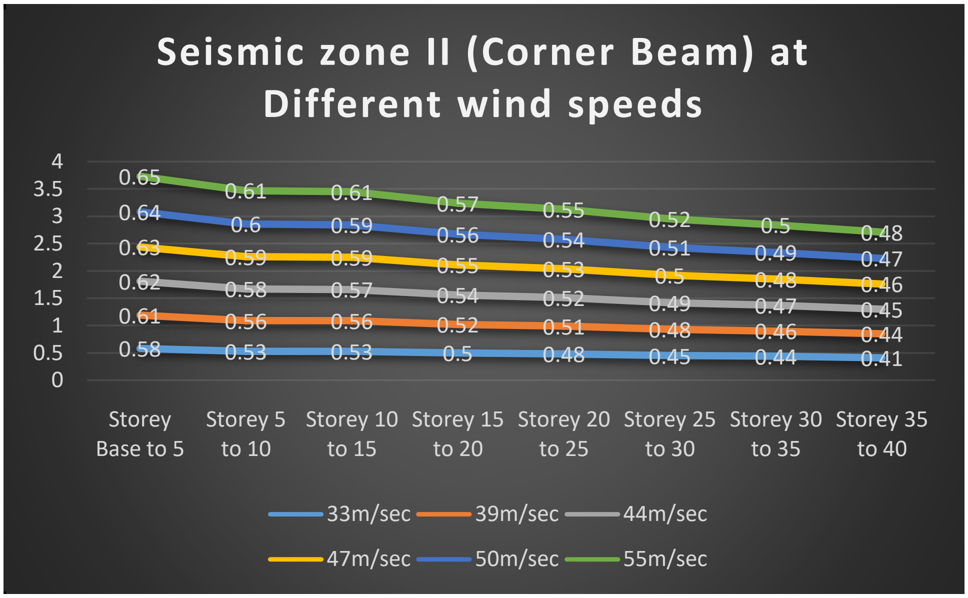

Fig.4 Beam coefficient for combination of seismic zone II (corner beam)

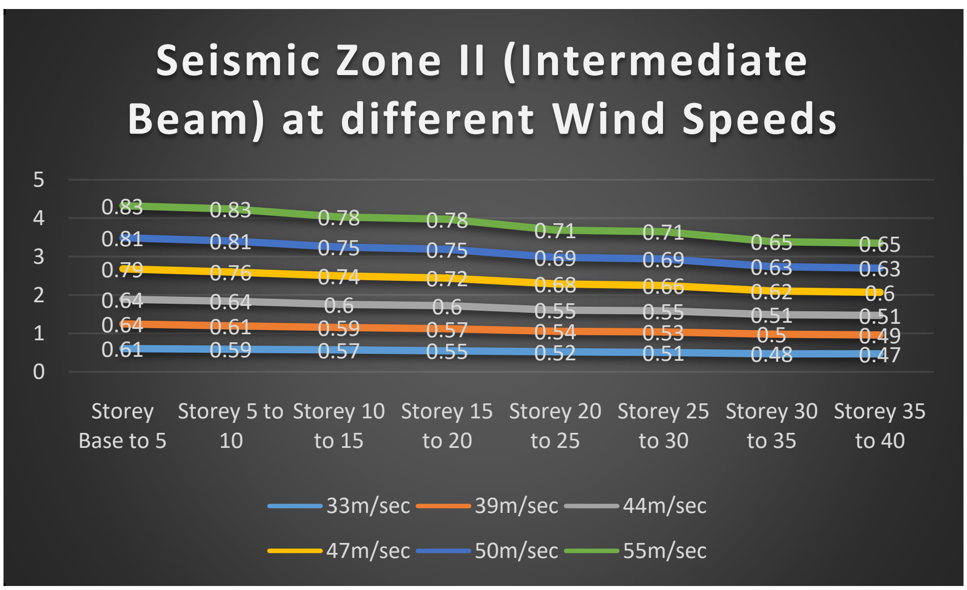

Fig.5 Beam coefficient for combination of seismic zone ii (intermediate beam)

From figure 4 and 5, the beam coefficient is changing from storey 1 to 40 and the steel coefficient is varying with the variation in speed that shows building in seismic zone II governing in wind zone (building is prone to wind resistant rather than seismic zone II for 40 storey building).

For combination of: Seismic Zone III- wind speed 33m/sec, 39m/sec, 44m/sec, 47m/sec, 50m/sec, 55m/sec.

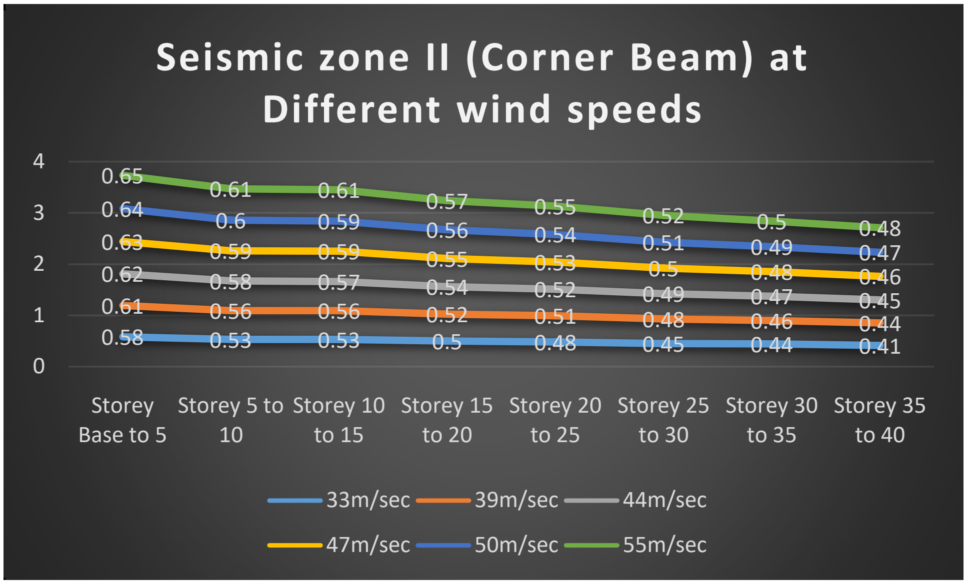

Fig.6 Beam Coefficient for combination of Seismic Zone III (corner beam)

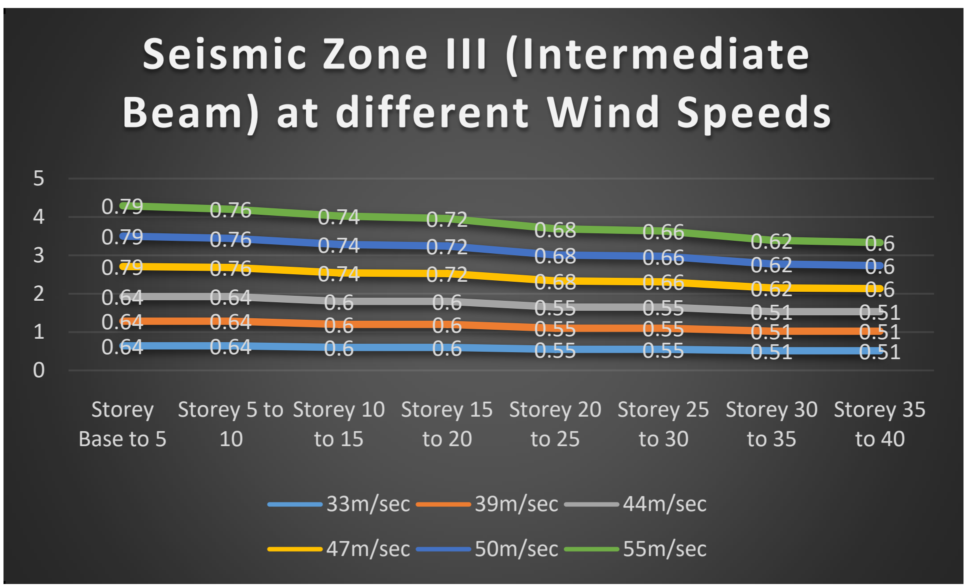

Fig.7 Beam Coefficient for combination of Seismic Zone III (Intermediate beam)

From figure 6 and 7, the beam coefficient is for seismic zone III is constant up to wind speed 44m/sec and start varying when the speed increases from 47m/sec to 55m/sec and gradually increasing the coefficient, it concludes that building is governing in wind for seismic zone III from wind speed 47m/sec to 55m/sec.

For combination of: Seismic Zone IV- wind speed 33m/sec, 39m/sec, 44m/sec, 47m/sec, 50m/sec, 55m/sec.

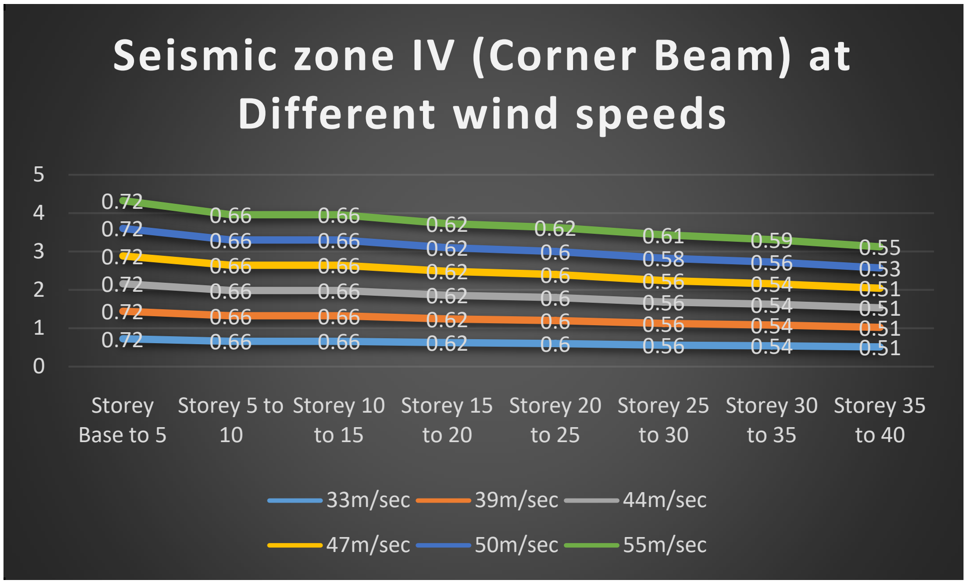

Fig.8 Beam Coefficient for combination of Seismic Zone IV (corner beam)

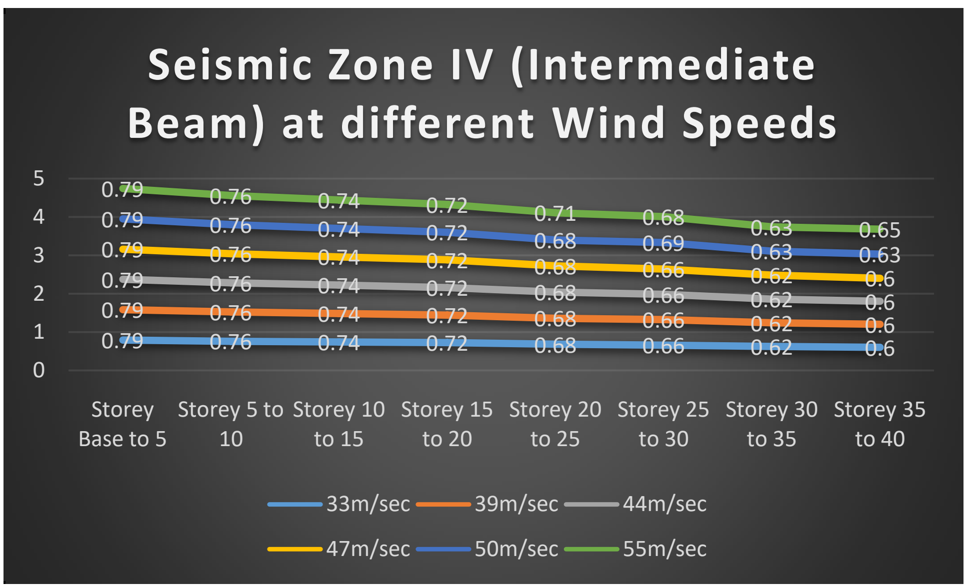

Fig.9 Beam Coefficient for combination of Seismic Zone IV (intermediate beam)

From figure 8 and 9, the beam coefficient for seismic zone IV is constant up to wind speed 47m/sec and start varying when the speed increases from 50m/sec to 55m/sec and gradually increasing the coefficient from storey 25 to 40 for 50m/sec wind speed and storey 35 to 40 for wind 55m/sec, it concludes that building is governing in wind for seismic zone IV from wind speed 50m/sec and 55m/sec.

For combination of: Seismic Zone V- wind speed 33m/sec, 39m/sec, 44m/sec, 47m/sec, 50m/sec, 55m/sec.

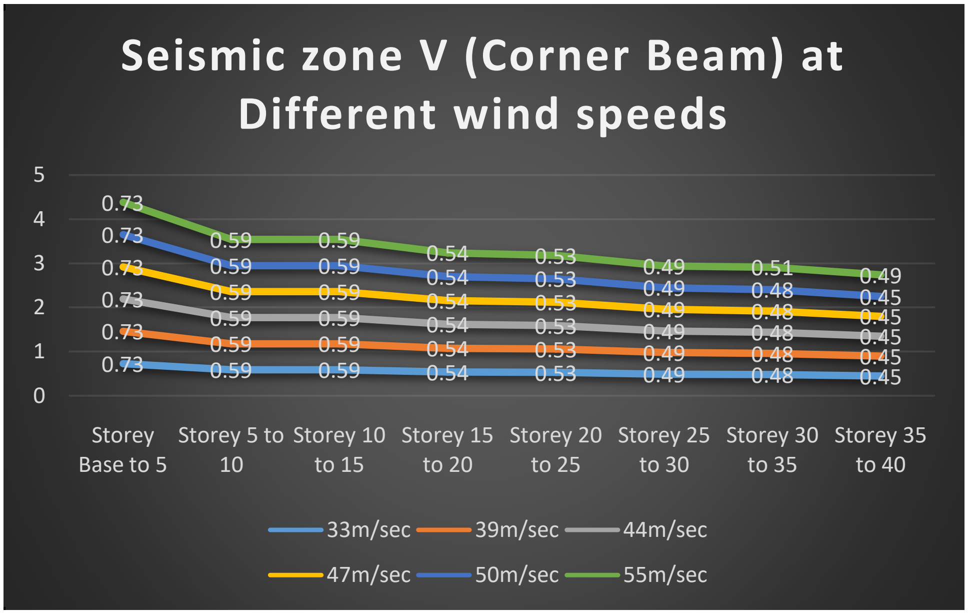

Fig.10 Beam Coefficient for combination of Seismic Zone V (corner beam)

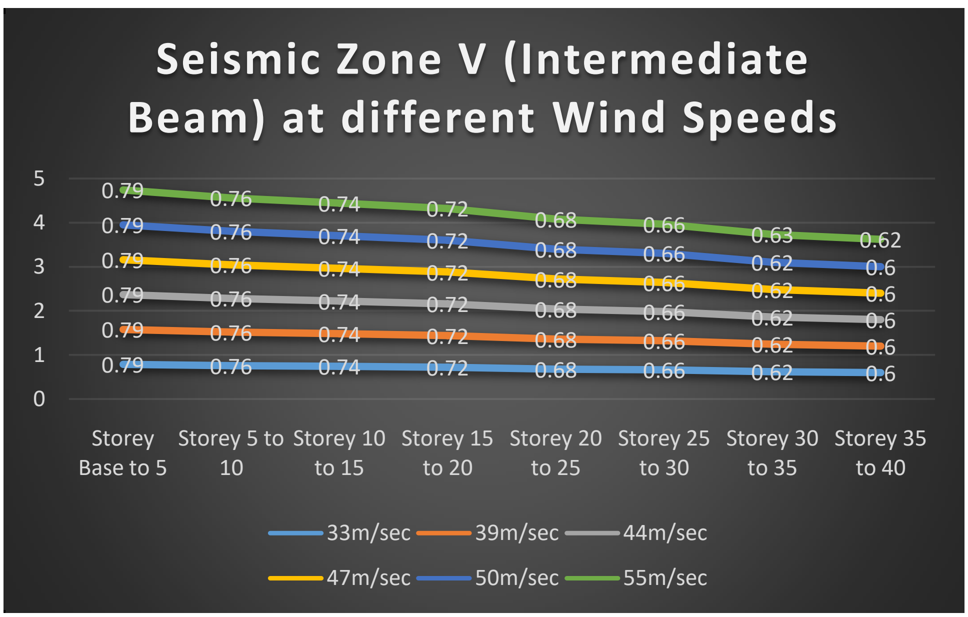

Fig.11 Beam Coefficient for combination of Seismic Zone V (intermediate beam)

From figure 10 and 11, the beam coefficient for seismic zone V is constant up to wind speed 50m/sec and vary when the speed increases to 55m/sec and gradually increasing the coefficient from storey 30 to 40 for 55m/sec it concludes that building is governing in wind for seismic zone V for wind speed 55m/sec.

B. Outcomes in Terms of Reinforcement Coefficient for Shear Walls

For combination of: Seismic Zone II- wind speed 33m/sec, 39m/sec, 44m/sec, 47m/sec, 50m/sec, 55m/sec.

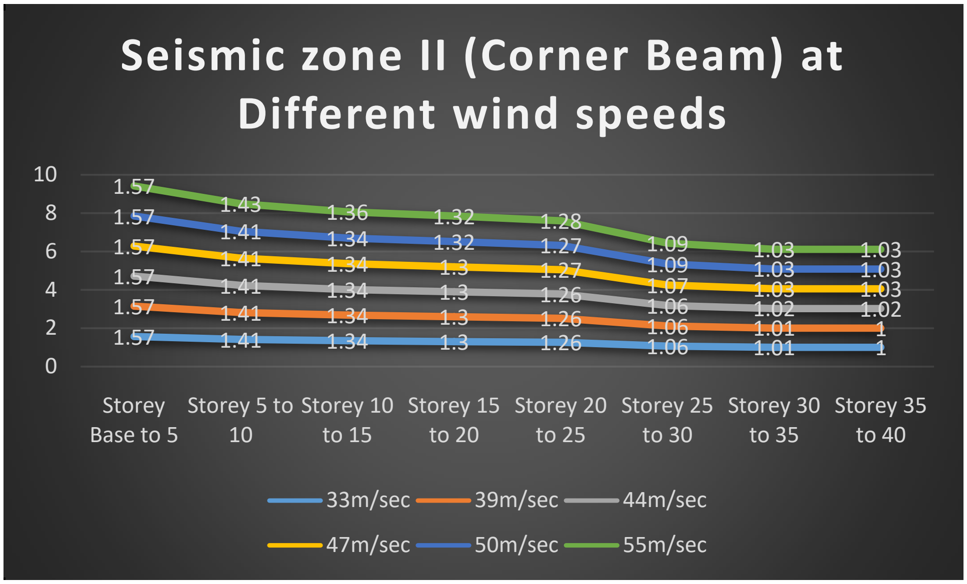

Fig.12 Wall Coefficient for combination of Seismic Zone II (corner beam)

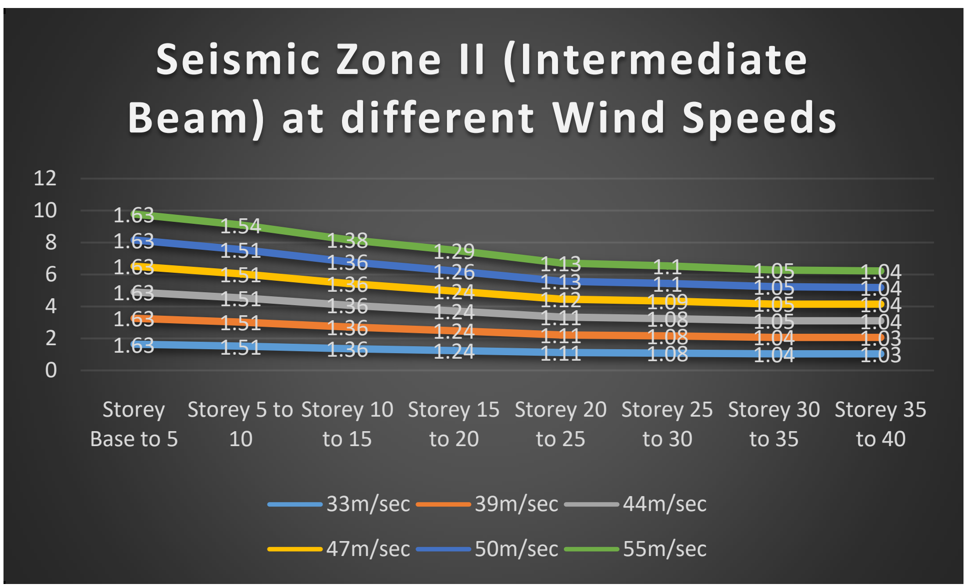

Fig.13 Wall Coefficient for combination of Seismic Zone II (intermediate beam)

From figure 12 and 13, the shear wall steel coefficient are changing from storey 1 to 40 and the steel coefficient is varying with the variation in speed that shows building in seismic zone II governing in wind zone (building is prone to wind resistant rather than seismic zone II for 40 storey building).

For combination of: Seismic Zone III- wind speed 33m/sec, 39m/sec, 44m/sec, 47m/sec, 50m/sec, 55m/sec.

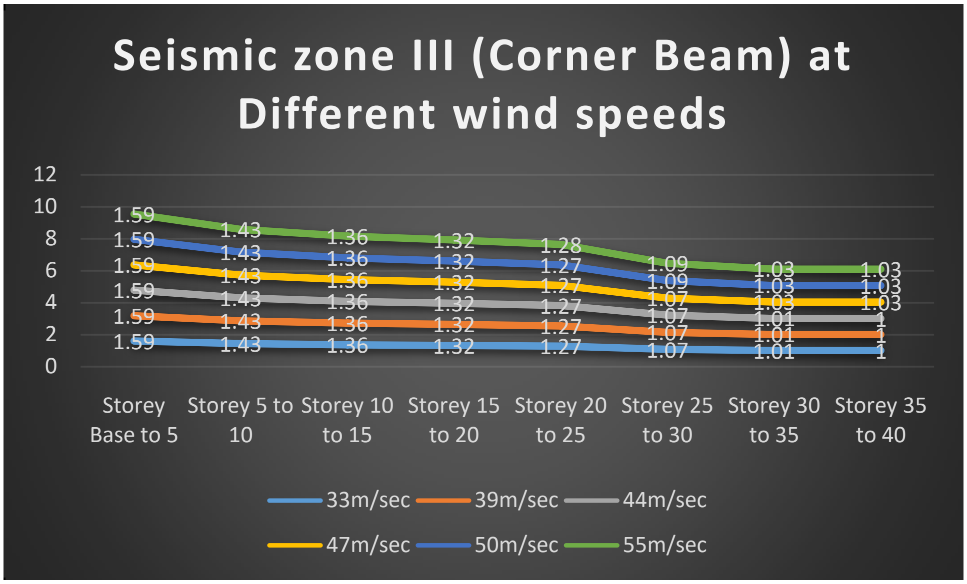

Fig.14 Wall Coefficient for combination of Seismic Zone III (corner beam)

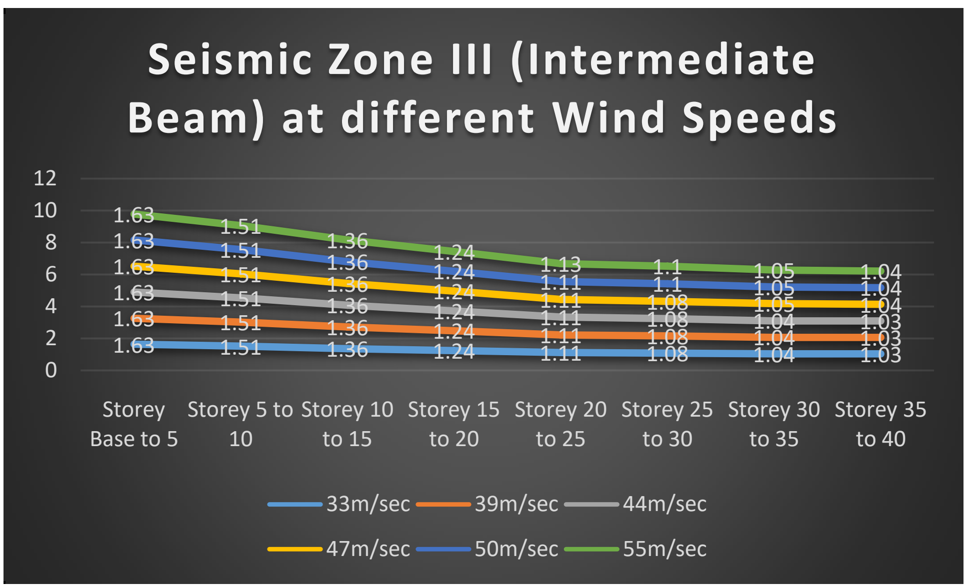

Fig.15 Wall Coefficient for combination of Seismic Zone II (intermediate beam)

From figure 14 and 15, the shear wall steel coefficient is for seismic zone III is constant up to wind speed 44m/sec and start varying when the speed increases from 47m/sec to 55m/sec and gradually increasing the coefficient, it concludes that building is governing in wind for seismic zone III from wind speed 47m/sec to 55m/sec.

For combination of: Seismic Zone IV- wind speed 33m/sec, 39m/sec, 44m/sec, 47m/sec, 50m/sec, 55m/sec.

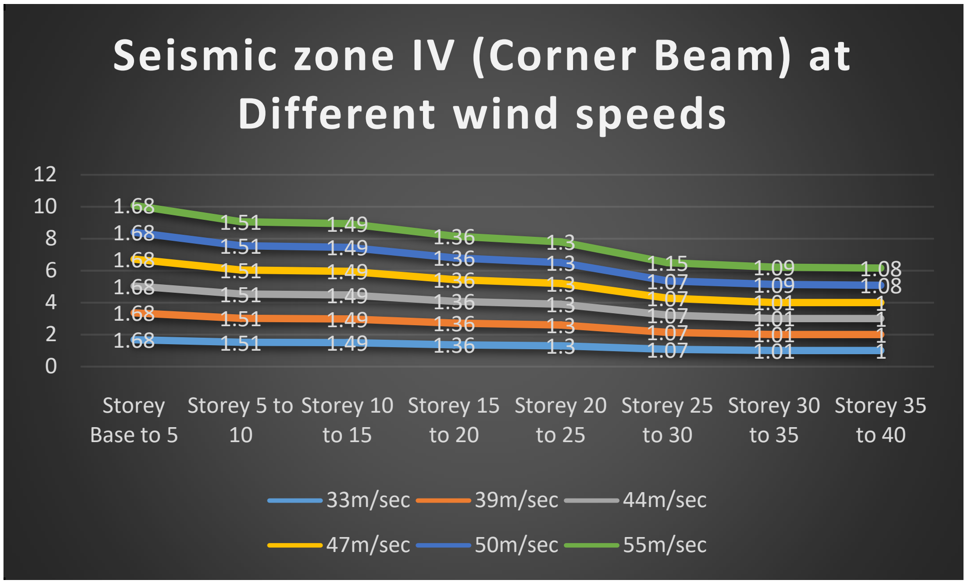

Fig.16 Wall Coefficient for combination of Seismic Zone IV (corner beam)

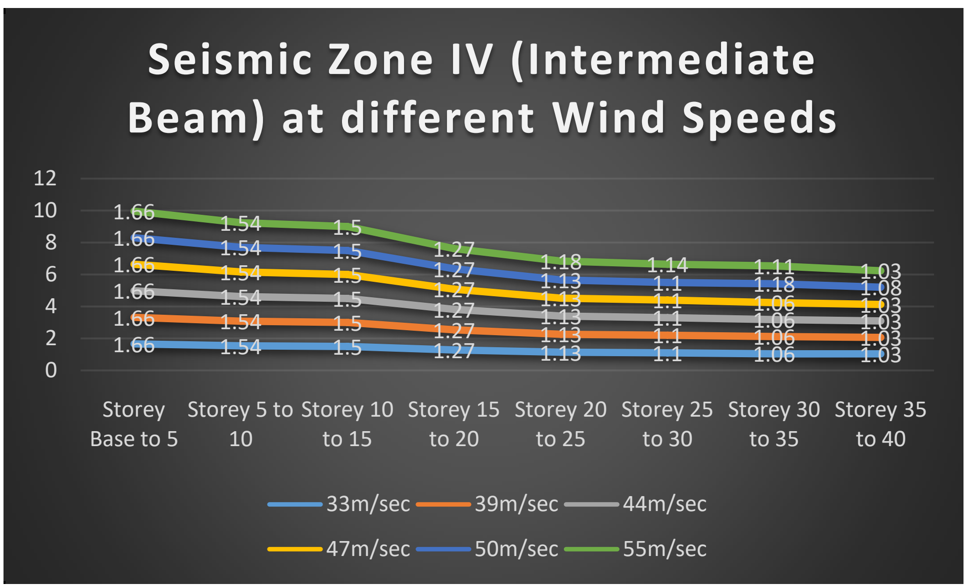

Fig.17 Wall Coefficient for combination of Seismic Zone IV (intermediate beam)

From figure 16 and 17, the beam coefficient for seismic zone IV is constant up to wind speed 47m/sec and start varying when the speed increases from 50m/sec to 55m/sec and gradually increasing the coefficient from storey 25 to 40 for 50m/sec wind speed and storey 35 to 40 for wind 55m/sec, it concludes that building is governing in wind for seismic zone IV from wind speed 50m/sec and 55m/sec.

For combination of: Seismic Zone V- wind speed 33m/sec, 39m/sec, 44m/sec, 47m/sec, 50m/sec, 55m/sec.

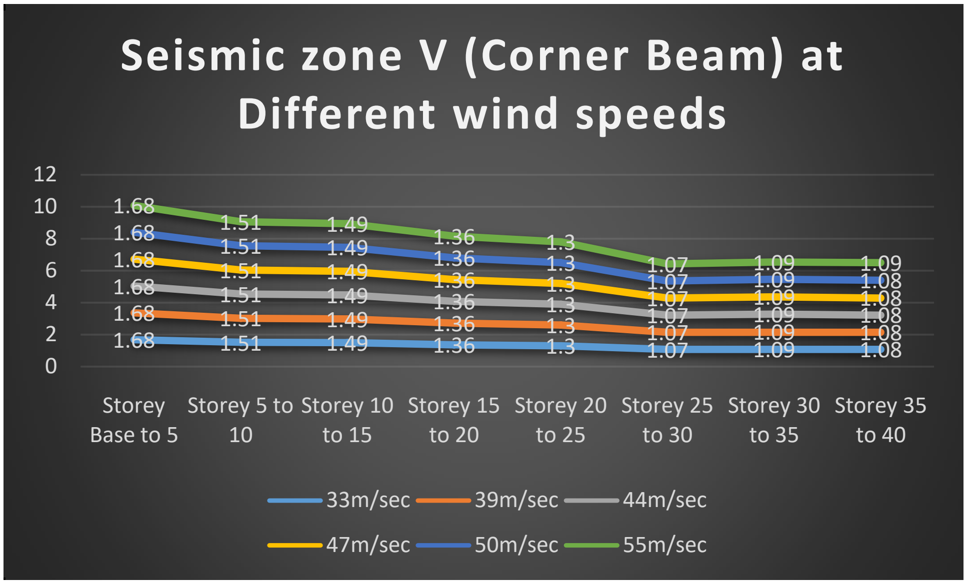

Fig.18 Wall Coefficient for combination of Seismic Zone V (corner beam)

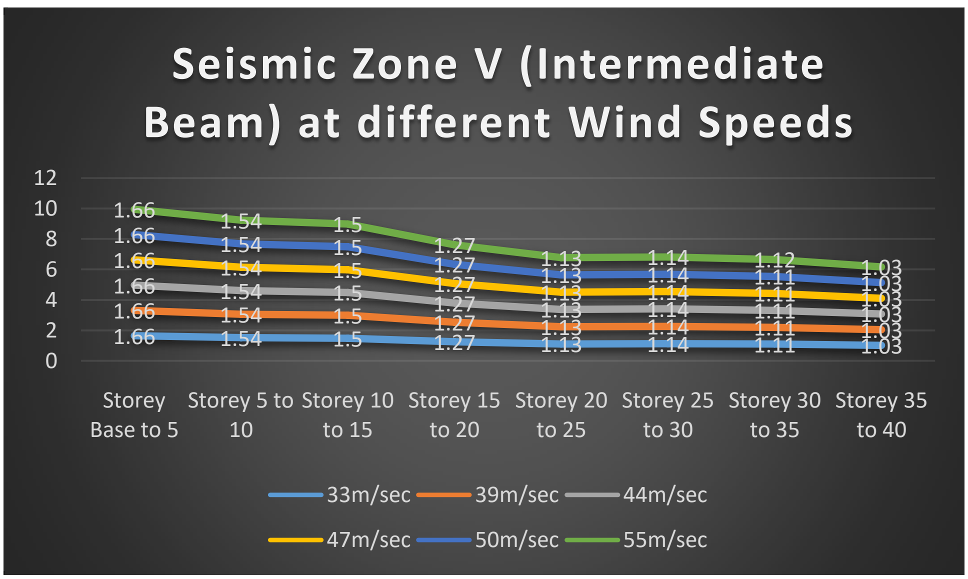

Fig.19 Wall Coefficient for combination of Seismic Zone V (intermediate beam)

From figure 18 and 19, the beam coefficient for seismic zone V is constant up to wind speed 50m/sec and vary when the speed increases to 55m/sec and gradually increasing the coefficient from storey 30 to 40 for 55m/sec it concludes that building is governing in wind for seismic zone V for wind speed 55m/sec.

VI. CONCLUSION

The variation of reinforcement as shown is different graphs shows that the building which is situated in Seismic Zone II generally governed by the wind forces more as compared to the seismic forces while the buildings which are situated in Seismic zone III are governed by wind forces when the wind speed is between 47m/sec to 55m/sec and before that they are governed by earthquake forces. Similarly building is governed by wind forces for seismic zone IV from wind speed 50m/sec and 55m/sec and below 50m/sec the earthquake force is the governing factor. For seismic zone V the earthquake forces are the governing factor for building design but when the wind speed crosses55m/s the wind forces becomes the governing factor. The above graphs also show the variation in reinforcement requirement as we increase the height of the building and this is taken into consideration for 40 storeys. The above results will be useful in future for further research and also will serve as a guiding parameter for designers.

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