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Evaluation of Effective Coupling Beam Width to Depth Ratios under Various Seismic Loads

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Abstract –*Earthquakes can cause damage and destruction of the buildings. Therefore, to withstand the effect of an earthquake, structural engineers and designers should give provisions for earthquake resistant structure with regards to planning, design, and detailing. To create earthquake resistant structures architects and structural engineers work on four aspects, namely seismic structural configuration, lateral strength, lateral stiffness, ductility and other aspects. In reinforced concrete building shear walls are used to resist earthquake force in high seismic zone due to its in-plane stiffness but when shear wall is constructed the problem of opening for door, window and ventilation occurs. So, use of Coupled shear wall i.e. shear wall with opening in RCC building could be an alternative solution for shear wall to attain functional flexibility in architecture. Shear wall behavior depends on wall positioning in building frame, wall thickness, material used and length of wall.*

***Key Words*: seismic load, coupling beam, shear wall, coupled shear wall, width to depth ratio, etabs 16**

1. INTRODUCTION

In this study, a 10 storey building with Coupled shear wall was designed to study the behaviour of building by varying the width to depth ratios of coupling beam. The horizontal member below and above the opening which connects two walls together is called as coupling beam. The beam is called as coupling beam because coupling action develops in the wall piers due to generation of large amount of shear force in beam. Coupled shear walls are built over the height of building with series of walls coupled by beam to accommodate opening for door, window, corridor and elevator well. The behaviour of coupled shear wall is greatly influenced by coupling system which depends on geometry and strength of coupling beam as compare with wall. The main parameter in coupled shear wall is stiffness ratio of coupling beam to wall pier, which depends on sizes of wall pier and coupling beam. The development of shear force in coupling beam results in formation of coupling action between wall piers. The different zone factors are used to analyse the building as per IS 1893 (Part1). These coupling beams are the primary source of dissipating seismic energy and are known for the large inelastic deformations or deformation controlled elements.

1.1 Coupled Shear Wall

Coupling beams and wall piers make construct a coupled shear wall. Shear walls are divided into pieces and joined by beams, resulting in an aperture between the walls. Coupled shear walls are constructed along the entire height of the building, with a succession of walls connected by a beam to permit openings for doors, windows, corridors, and elevator wells. The coupling system, which is based on the geometry and strength of the coupling beam in comparison to the wall, has a significant impact on the behaviour of a linked shear wall. The development of an axial force couple in the coupling beam is caused by the accumulation of shear in the coupling beam. An overturning moment is partially resisted by a couple that forms as a result of the development of axial compression–tension forces across the wall, rather than the wall's flexural action.

Light coupling results in an uncoupled wall, whereas over coupling results in a single wall with little or no energy dissipation by coupling beams. In a coupled shear wall, these types of systems are avoided.

1.2 Characteristics of Coupling effect

The main function of coupling beams is to transfer the high shear from one wall pier to the joined wall pier. Many Coupling beams are designed as flexural members with shear confinement which further leads to diagonal tension failure. To overcome the diagonal tension failure, diagonal bars are provided with proper confinements which are either in compression or in tension over the full length.

These coupling beams are the primary source of dissipating seismic energy and are known for the large inelastic deformations or deformation controlled elements.

2. METHODOLOGY

Equivalent Static Method - The lateral force produced by an earthquake is calculated using this method. The force is determined by the structure's fundamental time period, as described by IS 1893:2002. It's best suited to structures having a uniform mass and stiffness distribution. The base shear is computed first, and then distributed according to the formulas below in proportion to the height of the building.

The total design horizontal force or base shear (Vb) along any principal direction is calculated as,

$$Vb = Ah. W$$

Where W is the building's seismic weight.

The horizontal seismic coefficient Ah is calculated using the following formula:

Where Z denotes the zone factor. The importance factor is denoted by the letter I. R stands for the response reduction factor. The average response acceleration coefficient is referred to as

$$Sa/g$$

Total 24 models are analysed using ETABS, the width to depth ratios of 0.4, 0.45, 0.5, 0.55, 0.6, and 0.65 are varied under II, III, IV and V Seismic zones respectively. The zone factors are used for different ratios of width and depth in the coupling beams using IS 1893 (Part1).

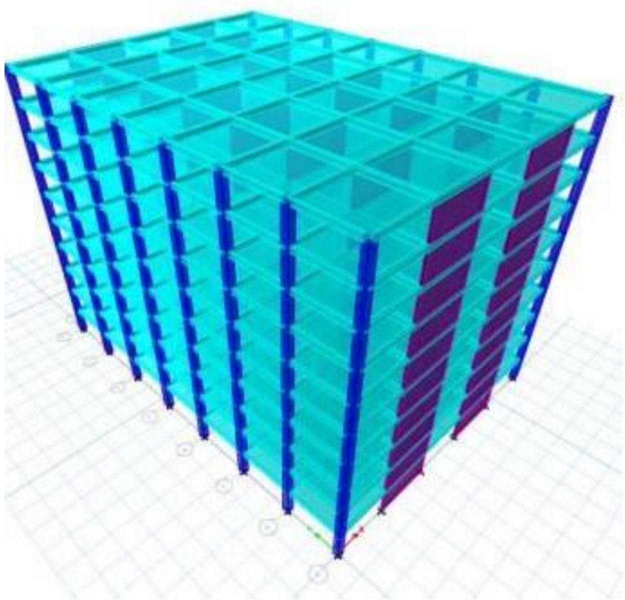

Fig -1: 3D view of model considered.

3. RESULTS AND EVALUATION

All the outcomes are obtained after successful completion of the model, after application of seismic loads for building with different width to depth ratio of coupling beam. As our aim is to analyse a building with coupled shear wall, as well as to know the building behaviour. Here we determined how the interconnected beam behaves and how the size of the coupling beam affects the system. The impact of varying the width-to-depth ratio on the shear walls are shown in the graphs.

3.1 Displacement

The lateral displacements obtained for response spectrum method (RSM) for 10 storey building models, along both X and Y directions are listed in the graphs below.

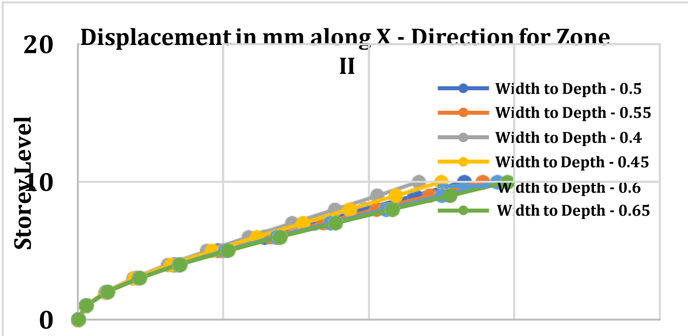

Fig -2: Zone II displacement in millimetres along X-axis

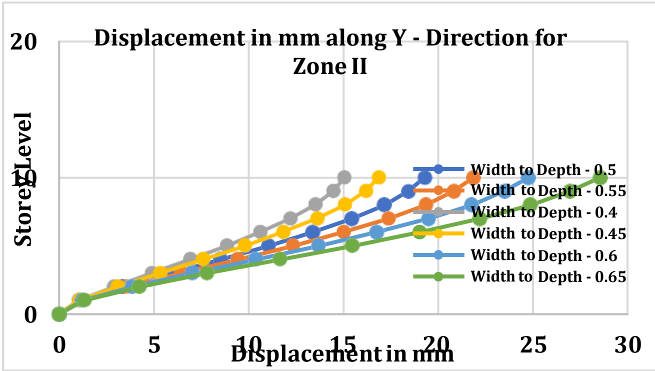

Fig -3: Zone II displacement in millimetres along Y-axis

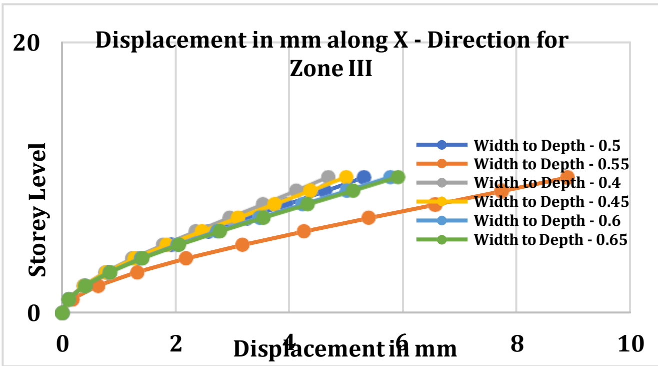

Fig -4: Zone III displacement in millimetres along X-axis

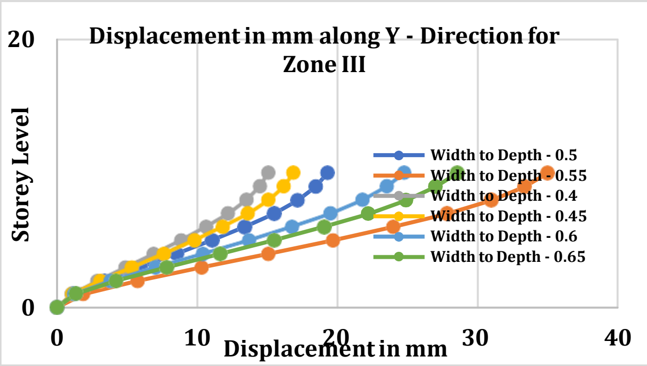

Fig -5: Zone III displacement in millimetres along Y-axis

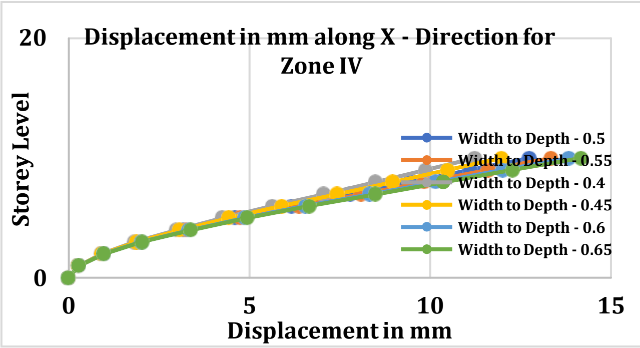

Fig -6: Zone IV displacement in millimetres along X-axis

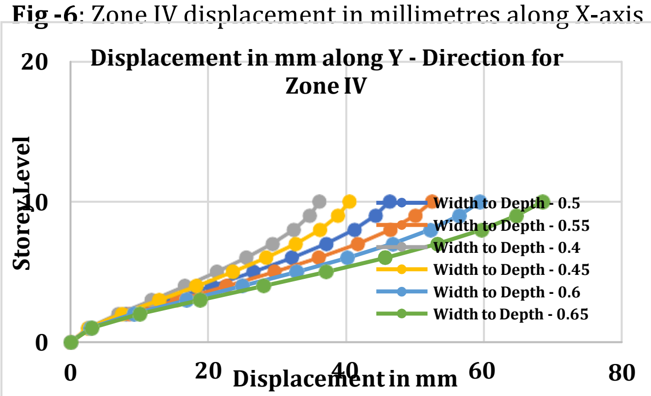

Fig -7: Zone IV displacement in millimetres along Y-axis

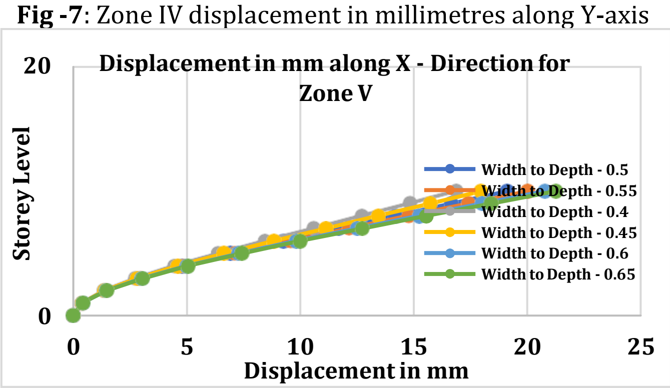

Fig -8: Zone V displacement in millimetres along X-axis

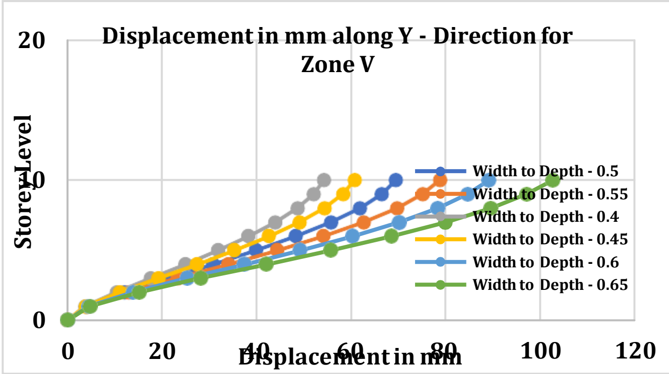

Fig -9: Zone V displacement in millimetres along Y-axis

The displacement in the lower stories are very less and however the storey height is increasing the displacement also goes on increases in all models for both directions. The storey displacement is increasing however the zone increase, for lower displacement in zone II and higher displacement in the zone V and however the width to depth ratios are increases the displacement also increases, i.e the width to depth ratio of 0.4 model is showing the lesser displacement as remaining all the in both direction and all the zones respectively.

3.2 STOREY DRIFT

It is defined as the ratio of the displacement of two consecutive floors to their height. It's a crucial phrase in earthquake engineering for research purposes. The storey drift computed for all 10 storey building models in both the X and Y directions is presented in the tables below for both Equivalent static.

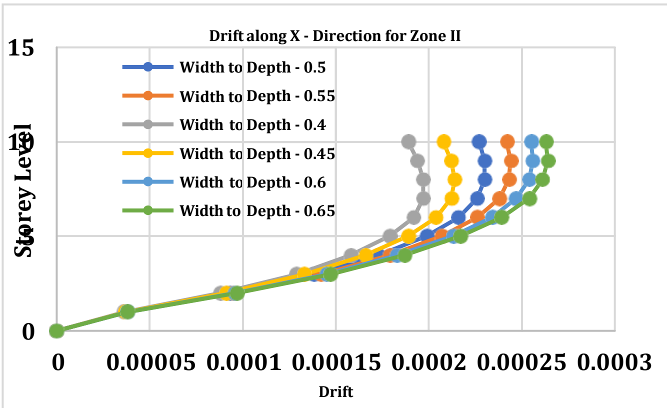

Fig -10: Zone II storey drift along X-axis

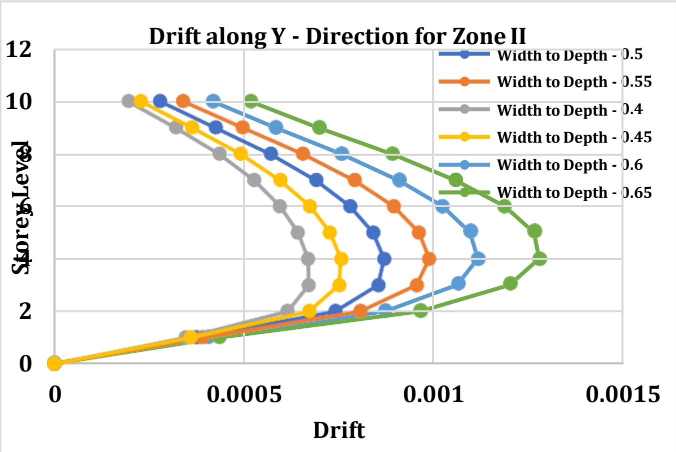

Fig -11: Zone II storey drift along Y-axis

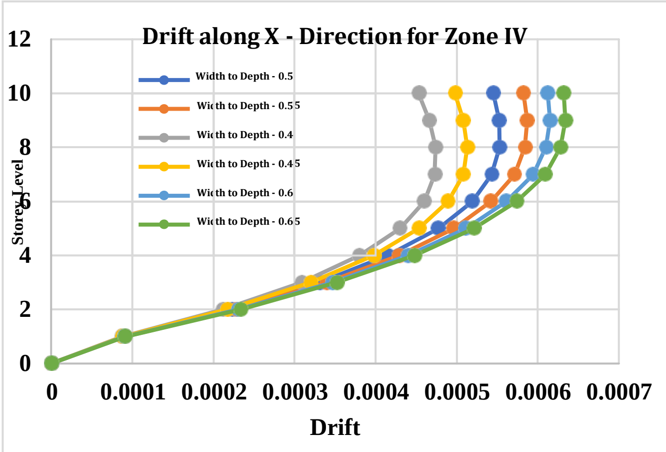

Fig -14: Zone IV storey drift ialong X-axis

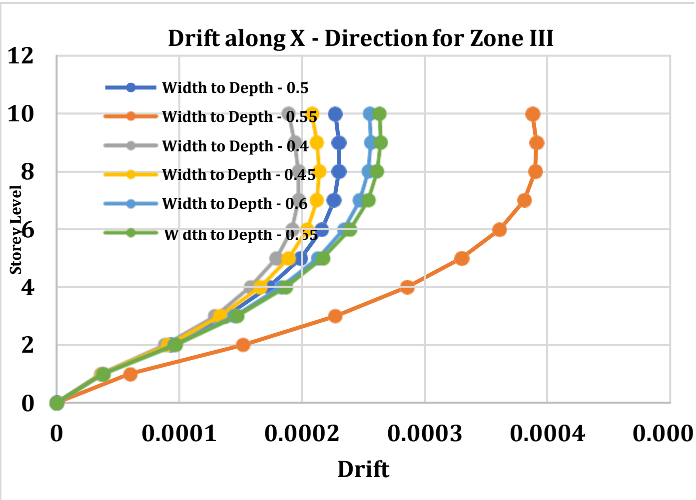

Fig -12: Zone III storey drift along X-axis

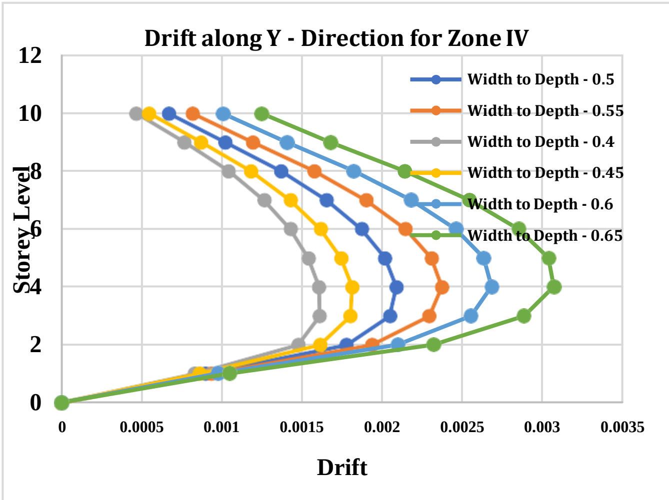

Fig -15: Zone IV storey drift along Y-axis

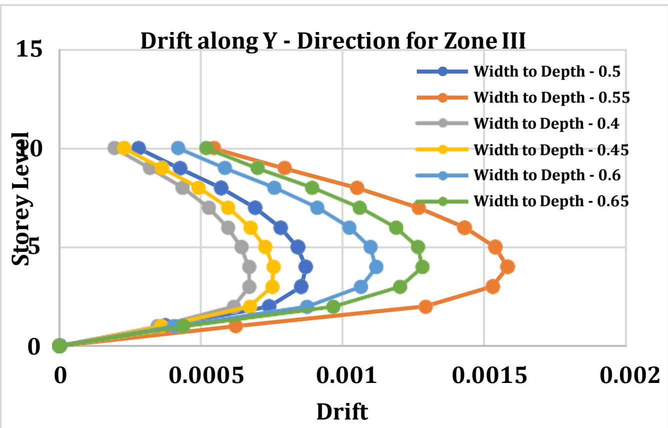

Fig -13: Zone III storey drift along Y-axis

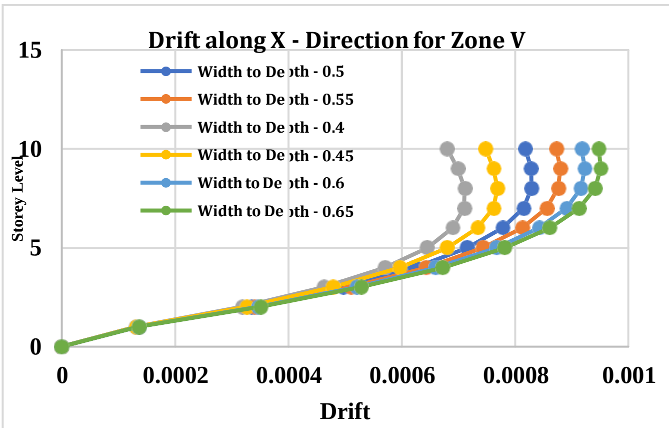

Fig -16: Zone V storey drift along X-axis

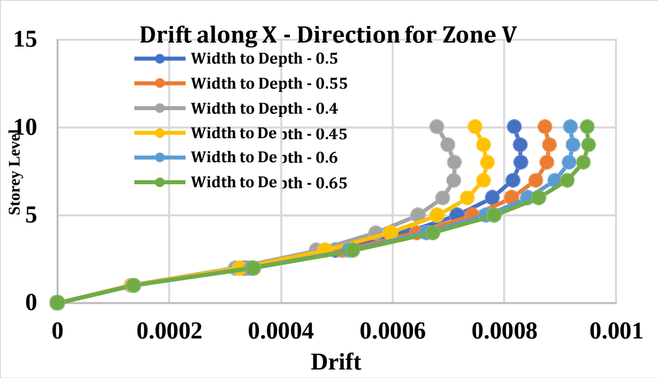

Fig -17: Zone V storey drift along Y-axis

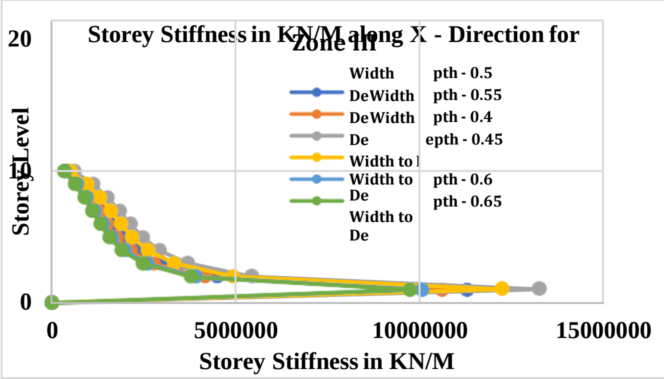

Fig -20: Zone III storey drift along X-axis

The storey drift in the lower stories are very less and however the storey height is increasing the storey drift also goes on increases in all models for both directions. The storey drift is increasing however the zone increase, for lower storey drift in zone II and higher drift in the zone V.

3.3 Storey Stiffness

Storey stiffness obtained for 10 storey all building models along both X and Y directions are listed for both Equivalent static in the below graphs.

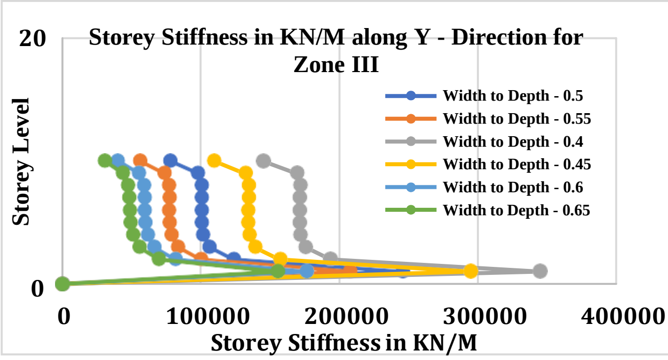

Fig -21: Zone III storey drift along Y-axis

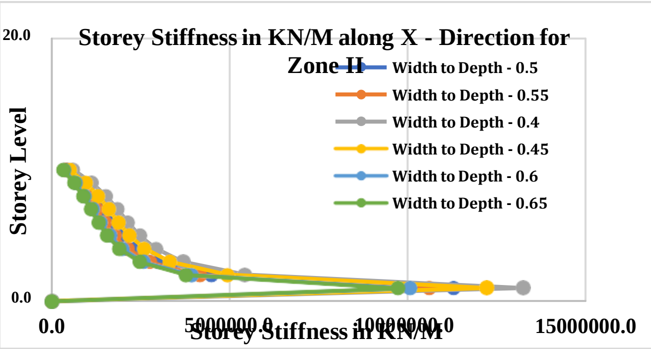

Fig -18: Zone II storey drift along X-axis

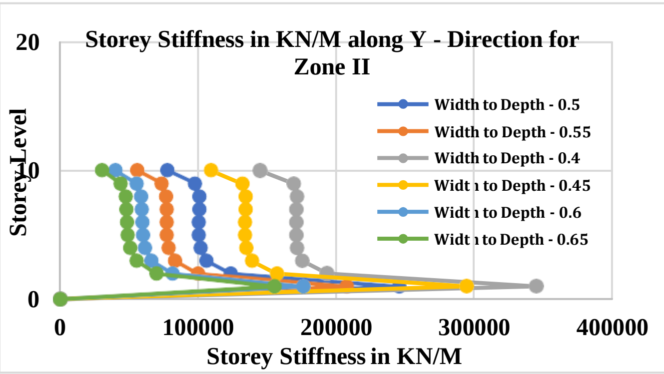

Fig -19: Zone II storey drift along Y-axis

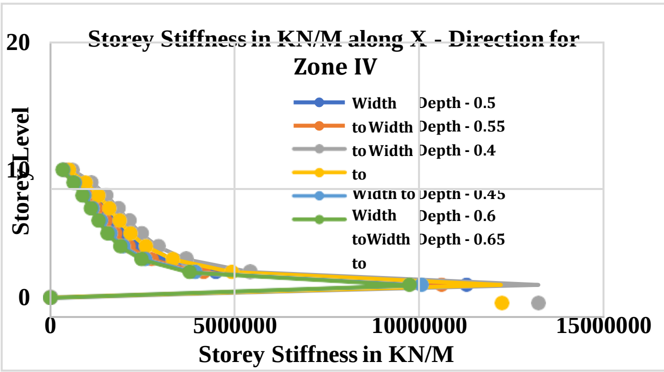

Fig -22: Zone IV storey drift along X-axis

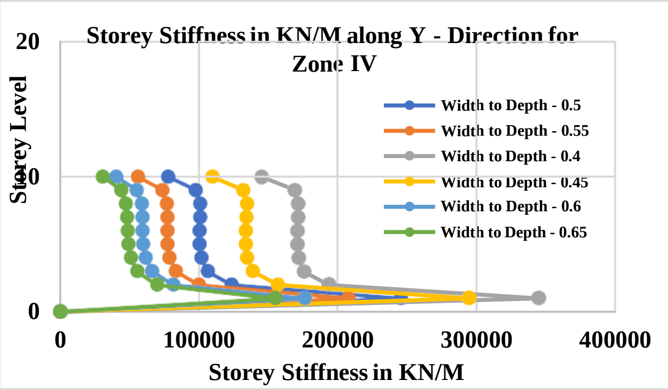

Fig -23: Zone IV storey drift along Y-axis

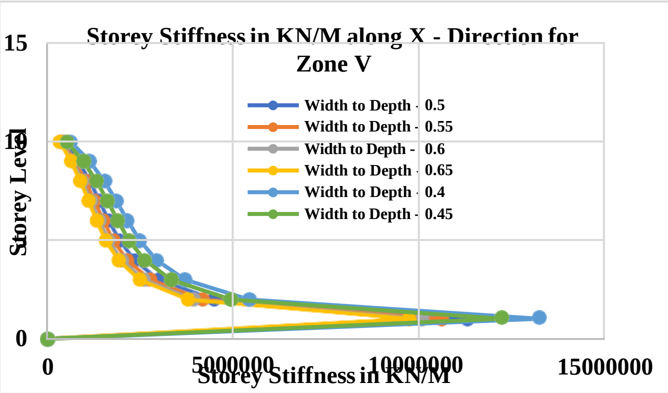

Fig -24: Zone V storey drift along X-axis

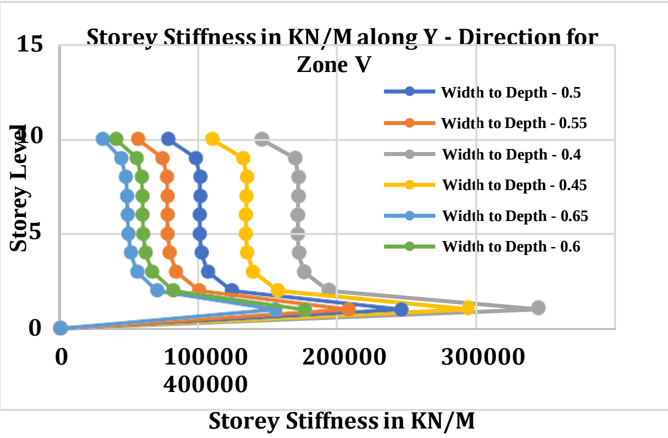

Fig -25: Zone V storey drift along Y-axis

The storey Stiffness is maximum at the lower stories and however the storey height is increasing the storey stiffness also goes on decreases in all models for both directions. The storey stiffness is increasing however the zone increase, for lower storey stiffness in zone II and higher stiffness in the zone V and however the width to depth ratios are increases the storey stiffness is decreases the width to depth ratio of 0.4 model is showing the higher storey stiffness as remaining all the models in both direction and all the zones respectively.

3.4 BASE SHEAR

Base shear is an estimate of the maximum expected lateral force on the base of the structure due to seismic activity. It is calculated using the seismic zone, soil material, and building code lateral force equations.

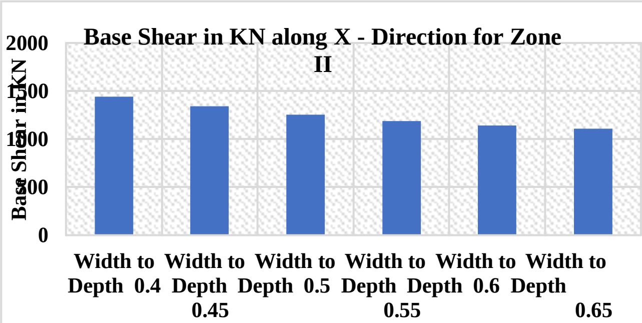

Fig -26: Zone II base shear along X-axis

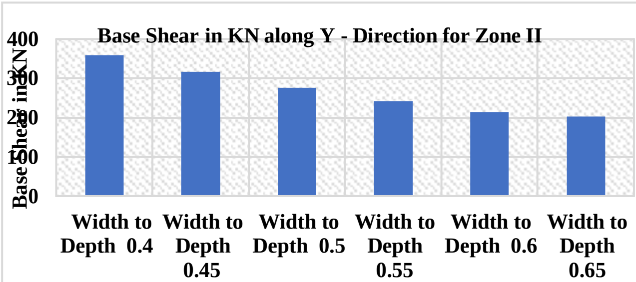

Fig -27: Zone II storey drift along Y-axis

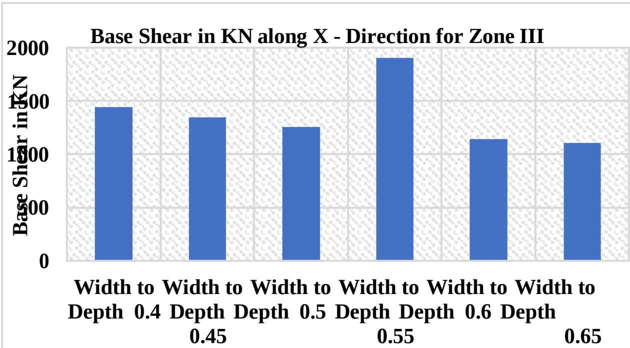

Fig -28: Zone III storey drift along X-axis

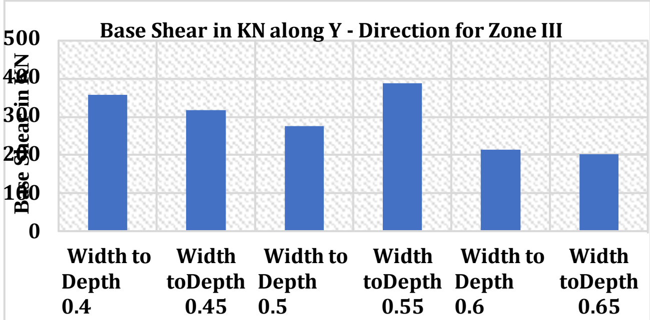

Fig -29: Zone III storey drift along Y-axis

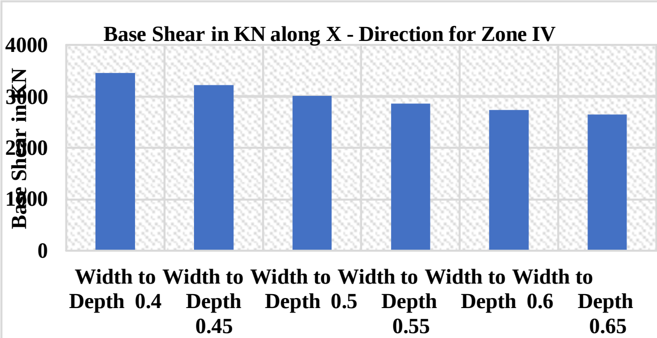

Fig -30: Zone IV storey drift along X-axis

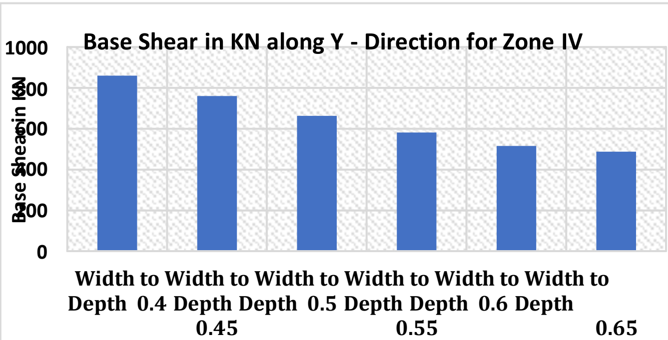

Fig -31: Zone IV storey drift along Y-axis

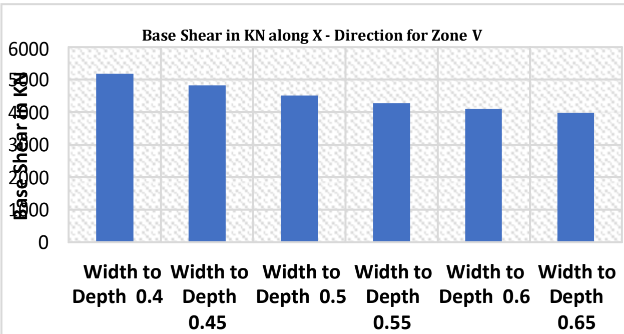

Fig -32: Zone V storey drift along X-axis

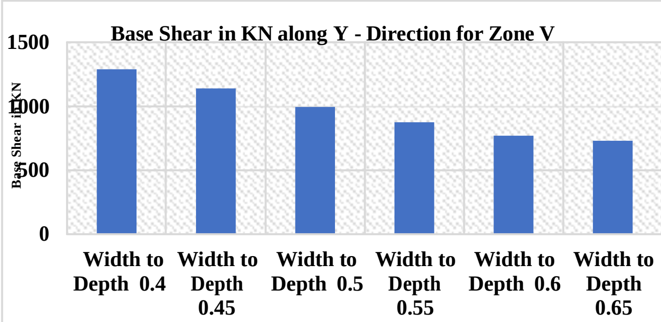

Fig -33: Zone V storey drift along X-axis

The base shear is maximum for width to depth ratios of 0.4 as compare to remaining all the structures and the building having the very low base shear for width to depth ratios of 0.6 and the however seismicity of the zone increases the base shear value also increases.

3.5 Time Period

Natural Period Tn of a building is the time taken by it to undergo one complete cycle of oscillation. The time periods of various models are extracted, tabulated and graphs are drawn and compared.

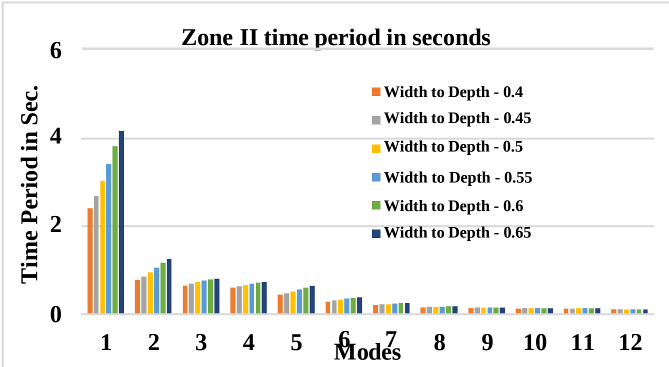

Fig -34: Zone II storey drift

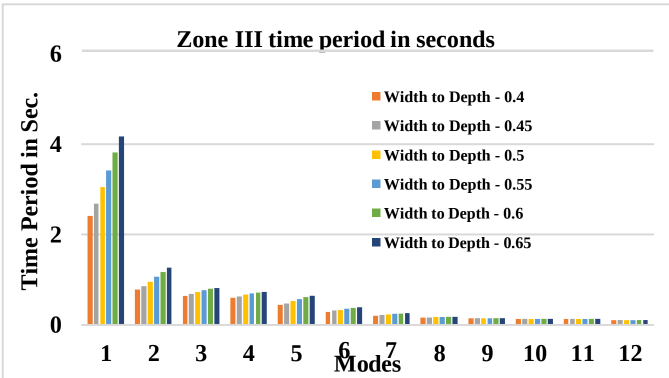

Fig -35: Zone III storey drift

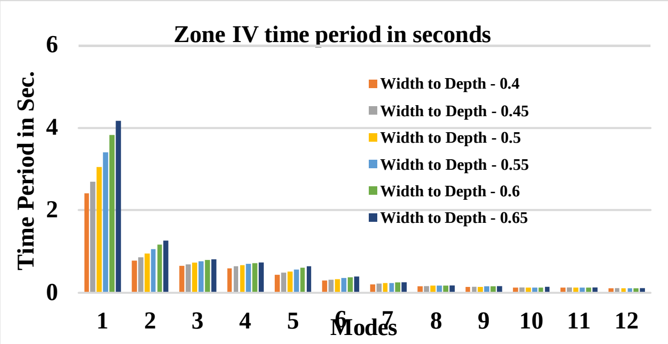

Fig -36: Zone IV storey drift

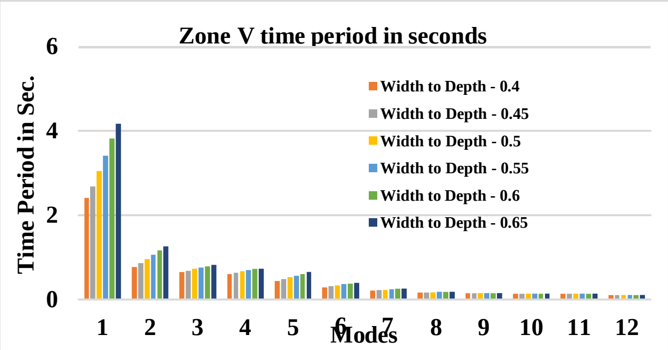

Fig -37: Zone V storey drift

The time period is maximum for width to depth ratios of 0.65 as compare to remaining all the structures and the building having the very low time period for width to depth ratios of 0.4 and the however seismicity of the zone increases the time period value also increases. In simple we can say that however the width to depth ratios increases the time period values are increasing.

4. CONCLUSION

Under earthquake load, a numerical study of a ten-story RCC building with a solid and connected shear wall is carried out. To understand the behaviour of RCC buildings with coupled shear walls, response quantities and performance requirements are compared to solid shear walls. However the width to depth ratio increases the displacement also goes on creases. RCC building with coupled shear wall having width to depth ratio of 0.4 of coupling beam is showing the lesser storey drift as compare to the width to depth ratios of 0.65. The width to depth ratios of 0.4 is showing the higher base shear and width to depth ratio of 0.65 is showing the lesser base shear. We can conclude the along the incremental of width to depth ratio the base shear is decreases. All seismic parameters considered for the thesis is within the permissible limit as is code.

We can conclude that the width to depth ratio of 0.4 is showing the very stable structure as compared.

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