Tall Structure Seismic Behaviour Analysis with Solid and Coupled Shear Walls

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ABSTRACT

The construction of high rise structures increases due to shortage of land and rapid growth of population. Introduction of advancement in construction materials and structural systems against lateral loads designer will achieve structural efficiency, aesthetic appearance and geometric versatility. Shear walls are structural systems which provide stability to structures from lateral loads. Coupled shear walls are one of the system commonly used in medium and high rise structures to resist lateral loads. When two shear walls are interconnected by beams along their heights then it is called as coupled shear wall. These building systems should not collapse or be induced to severe damage during earthquake actions due to high strength, high ductility, high energy absorption capacity and high shear stiffness to limit lateral deformation. In Coupled shear wall structure, major portion of lateral load is taken by the Coupled shear wall members, when intern releases forces to other members of the structure. This also reduces sectional requirement of the beams and columns in Coupled shear wall building. In the present study, the structural response of conventional, Shear wall and Coupled shear wall with different location investigated to evaluate structural system benefits. A building of G+11 storeys with plan size 23.2m x 17.4m, located in a seismic Zone V is considered and analyzed by ETABS 2016 Software. Nine models, i .e conventional frame structure, Shear wall in different location and Coupled shear wall in different location with same plan area are considered for study. All structural members are analysed as per Indian Standard codes. Comparison of analysis result in terms of Time Period, Storey Shear, Storey displacement Storey Drift, Storey Stiffness of structure is presented. From the analysis results it is observed that, the Coupled shear wall structures along X direction performs better in terms Time Period, Storey Shear, Storey displacement, Storey Drift, Storey Stiffness. Coupled shear wall in intermediate X and Y direction shows more weight difference compared to shear wall.

Keywords: High rise structures, shear walls, conventional frame structure, plan, time period, storey shear, storey displacement storey drift, storey stiffness

INTRODUCTION:

In most of the developing countries, especially in Asian countries, the available area of land decreases as the growth of population increases. This in turn has resulted in an increase in the number of high rise structures with numerous architectural configuration and structural materials. Around 60% of area lies in earthquake prone zone in India. So a responsible designer should focus on behavioural pattern of earthquake and develop earthquake resistant buildings to overcome affecting seismic activities. In recent years some structural systems are considered to be rigid frame, braced frame, in filled masonry walls, shear walls, coupled shear walls, outrigger systems etc. which resist horizontal load and gravity load in high rise buildings. But due to the increase in the height of the building, the stiffness of the structure becomes more important and introduction of lateral load resisting systems provides sufficient lateral stiffness to the structure. The lateral load resisting system controls the excessive1drift effectively due to lateral load during small or medium effect of wind or earthquake load. By this risk of structural and non-structural damage can be minimized to a greater extent. For high-rise buildings, particularly in seismic active zone or wind load dominant, the shear wall systems are considered to be among the most appropriate structural systems.

Shear walls are most common structural system used in high rise structures. Shear walls are divided into two types; core shear wall and solid shear wall. Solid shear wall gives more resistance to the structure under seismic activities. Coupled shear wall is a type of shear wall which is commonly used for medium to high rise structures in seismic active regions. This provides adequate strength and deformation capacity to ensure satisfactory performance during an earthquake. In recent days the structure walls with openings like windows, doors and service ducts which result in simple shear walls to coupled shear walls.

The coupled shear wall is a part of shear wall consisting of coupling beams and wall piers. Shear walls start at foundation and continue till the height of building. Coupled shear wall performs better during an earthquake and gives a functional flexibility in architecture. As a result of coupling the over turning moment is resisted by partially an axial compression-tension couple across the wall system rather than individual flexural action of walls. The lateral load resisting members must be ductile and strong enough to absorb and dissipate energy by inelastic behaviour.

The shear walls are coupled by beams or by floor slabs or combination of both elements. The purpose of coupling beams is to make coupled shear wall as a single composite cantilever unit and it improves the lateral stiffness compared to uncoupled shear wall. The presence of coupling beam increases the axial force and there by decreases bending moment and lateral deflection.

REVIEW OF LITERATURE:

Researchers have studied Coupled Shear Walls and its behaviour against different load combinations and compared with conventional frame structures respectively. From the literature review it is observed that the coupled shear wall performs better against earthquake and gravity loads. The performance of conventional framed structure, shear wall structures and coupled shear wall structures with different location for rectangular shape are studied and its performance against lateral loads and gravity loads are compared. In the present research work, the Time Period, Stiffness, Storey shear, Storey Displacement of the structures are thoroughly studied for without Shear Wall, with Shear Wall and Coupled Shear Wall at different location.

PROBLEM DEFINITION:

The increasing growth of population and decreasing in land area in developing countries and rapidly growing cities are two major problems. These problems are satisfied by the construction of multi-storey buildings using advance technology. The high rise structure design mainly depends on lateral forces; it may be wind or earthquake. Structural systems are used to resist these forces and they effectively satisfy the design elements. Structural Systems called Shear wall and Coupled Shear wall are widely used nowadays in constructing tall buildings. Configuration and flexibility in plan are achieved as a better choice under lateral loads because of its structural efficiency. The present study focuses on the comparison between conventional frame structures, Shear1wall and Coupled1Shear1wall structures with different location of walls and discusses the performance structures under lateral loads. In this investigation, a comparison study is done between Conventional frame structure, shear1wall structure and Coupled shear1walls at different location. For modelling and analysis ETABS software is used.

A symmetrical G+11 building is considered for all models. To check the performance of the building under earthquake, zone V and medium soil condition is considered. Floor height is considered as 3 m for all stories. Behavior1of shear1wall and coupled shear wall structure with different location is studied.

OBJECTIVES OF THE STUDY:

The following are the objectives of present study.

- To study the conception of Coupled shear wall structural system.
- To investigate the performance of Coupled shear wall building under seismic condition- Zone V and medium soil.
- Analysis and comparison of buildings under seismic condition with different models.
- Time Period, Stiffness, Storey shear, Storey displacement and Storey drift of all models are analyzed.

METHODOLOGY:

Steps Followed to forming Model in ETABS Software:
The AutoCAD file is imported to ETABS and the model is developed in ETABS by following procedure. Define the material & sections → Add Beam, columns, slabs & shear wall →Assign Loads for different structural elements →Assign support conditions →Select preferred code → Define load combination →Check for model →Analyze →Concrete Design →Export of results.

Method of Analysis of Structures:
To ensure the safety1against seismic1actions1of1the building1there1is need to carry a seismic investigation of the structure. The investigation can be performed on1the1premise of external activity, the behavior1of structure or basic materials, and the types of basic model choose. Based on type of outer activity and behaviour of structure, the investigation can1be classified as,

a. Linear Static Method (Equivalent Static Analysis)
b. Non-Linear Static Method (Push Over Analysis)
c. Linear Dynamic Analysis (Response Spectrum Analysis)
d. Non-Linear Dynamic Analysis (Time History Analysis)

Description of Model:
In this research a symmetrical building of G+11 stories are considered for study. The plan area 23.2 m x17.4 m is constant for all type of model. For analysis ETABS 2016 is used. Details of building are given below.

Building Parameters:

a. Number of Storey - G+11
b. Typical Storey Height- 3m
c. Basement Height – 3m
d. Building Height – 36 m
e. Concrete Grade – M25
f. Steel Grade - Fe 415
g. Slab Thickness- 150 mm
h. Area of the Plan- 23.2m x17.4 m
i. Dimension in X direction – 23.2 m (4 bays of 5.8 m each)
j. Dimension in Y direction – 17.4m (3 bays of 5.8 m each)
k. Structure Type – Special moment resisting frame base pinned

Seismic Data (As per 1893, Part 1:1983):

a. Zone factor – 0.36 (V)
b. Response1Reduction1Factor, R- 5 (SMRF)
c. Importance1factor, I – 1
d. Types of soil -II (Medium1Soil)

Loading Data:

a. Live loads for Floors – 3 k N /m²
b. For Roofs -1.5 k N/m²
c. Floor finish – 1 k N/ m²

Load Combinations:
The load combinations as per IS codes are considered for modelling are shown below.

a. 1.5DL+1.5LL
b. 1.5DL+1.5EQX
c. 1.5DL-1.5EQX
d. 1.5DL+1.5EQY
e. 1.5DL-1.5EQY
f. 1.2DL+1.2LL+1.2EQX
g. 1.2DL+1.2LL-1.2EQX
h. 1.2DL+1.2LL+1.2EQY
i. 1.2DL+1.2LL-1.2EQY

Structural Models:

Table 1: Section Properties of the structural models

Building	Type	Location of shear wall/Coupled shear wall	Size of members
12 storey	Conventional Structure	M1-Conventional Structure	Beam-300x450mm Column-400x500mm (1st to 6th storey) Column-300x450mm (7th to12th storey)
	Structure with Shear Wall	M2-Position of shear wall all around with openings **(ASW)**. M3-Position of Shear wall in X direction (SW). M4-Position of Shear wall **(SW)** in Y direction. M5-Position of intermediate Shear wall (**ICSW)** in X & Y direction.	Beam-300x450mm Column-400x500mm (1st to 6th storey) Column-300x450mm (7th to12th storey) Shear wall thickness-230mm
	Structure with Coupled Shear Wall	M6-Position of Coupled shear wall all around **(ASW).** M7-Position of Coupled shear wall **(CSW)** in X direction. M8-Position of Coupled shear wall **(CSW)** in Y direction. M9-Position of intermediate Coupled shear wall **(ICSW)** in X and Y direction.	Beam-300x450mm ColUmn-400x500mm (1st to6th storey) Column-300x450mm (7th to12th storey) Coupling beam: Depth-700mm Length-1.8m Shear wall length-2m Shear Wall thickness-230mm

Plan and view of all models:

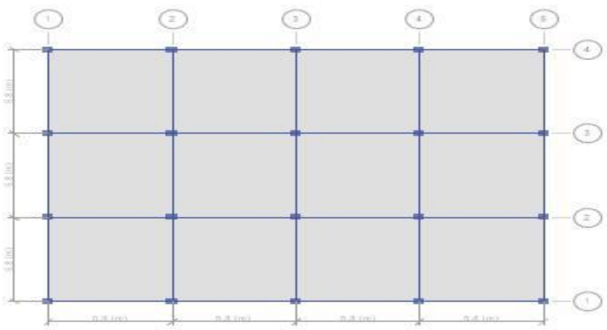

Fig. 1: Plan of Conventional Building (M1)

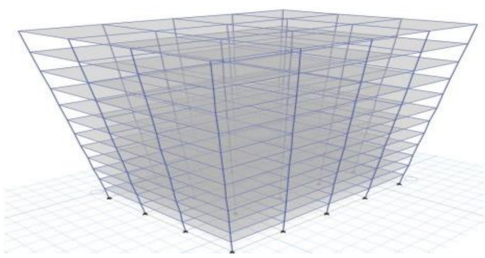

Fig. 2: 3D View of Conventional Building (M1)

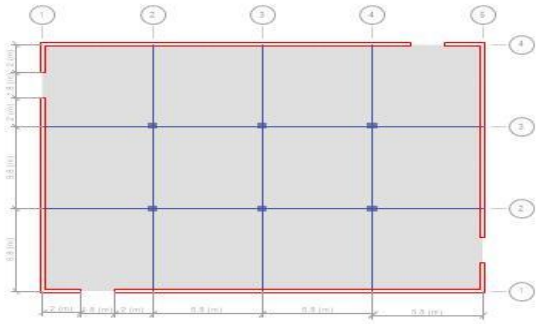

Fig. 3: Plan of ASW with opening (M2)

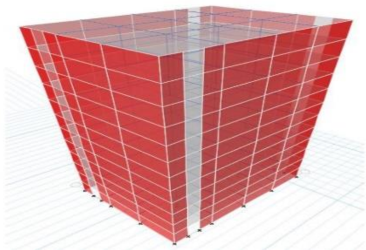

Fig. 4: 3D View of ASW with opening (M2)

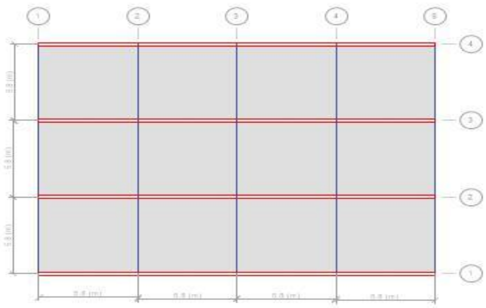

Fig. 5: Plan of SW in X Direction (M3)

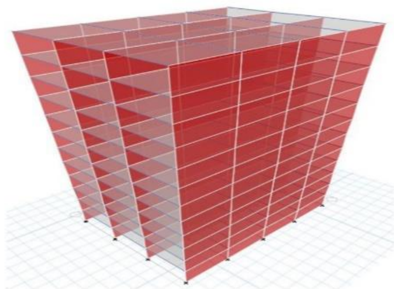

Fig. 6: 3D View of SW in X Direction (M3)

Fig. 7: Plan of SW in Y Direction (M4)

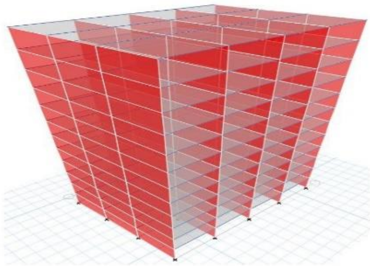

Fig. 8: 3D View of SW in Y Direction (M4)

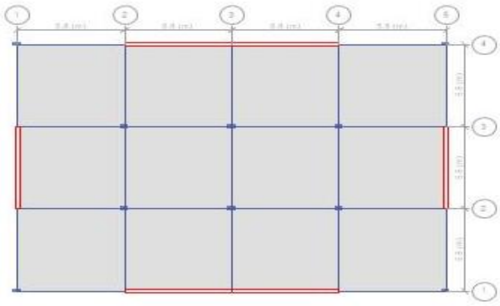

Fig. 9: Plan of ISW X & Y Direction (M5)

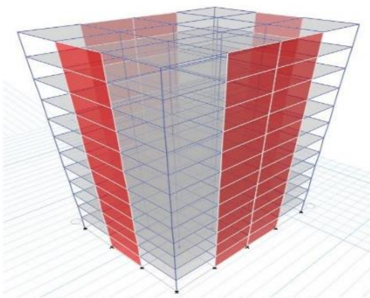

Fig. 10: 3D View of ISW in X & Y Direction (M5)

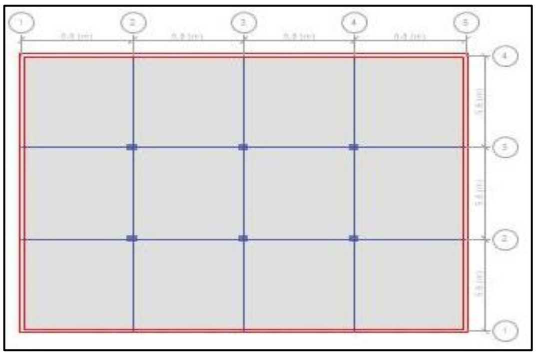

Fig. 11: Plan of all around CSW (M6)

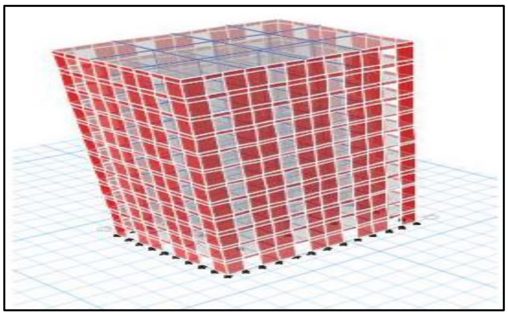

Fig. 12: Plan of all around CSW (M6)

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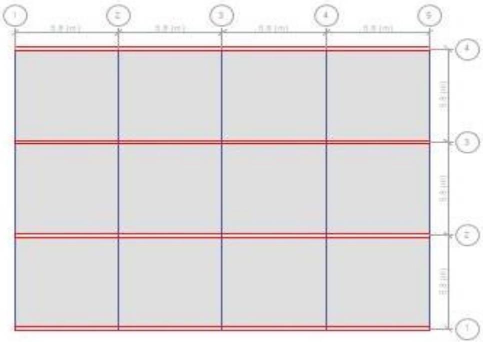

Fig. 13: Plan of CSW in X Direction (M7)

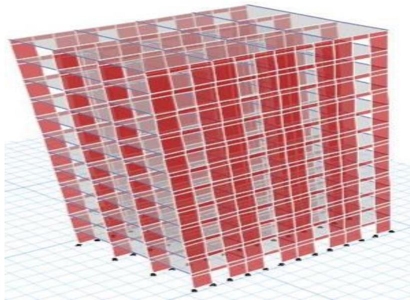

Fig. 14: Plan of CSW in X Direction (M7)

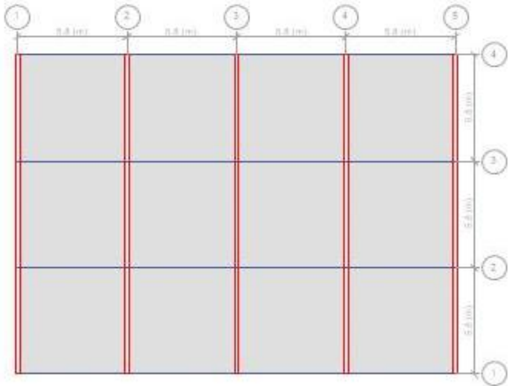

Fig. 15: Plan of CSW in Y Direction (M8)

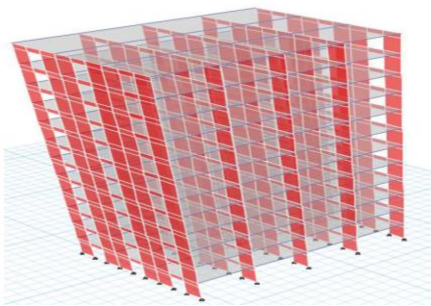

Fig. 16: Plan of CSW in Y Direction (M8)

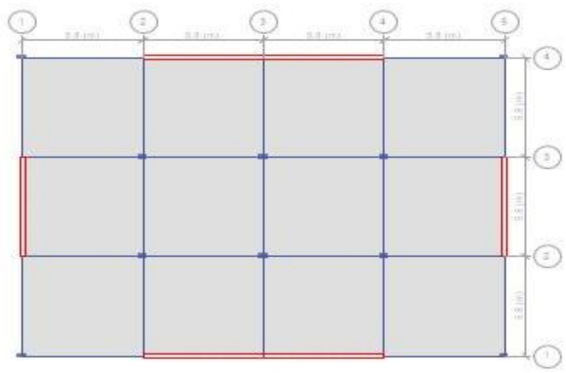

Fig. 17: Plan of ICSW in XY Direction (M9)

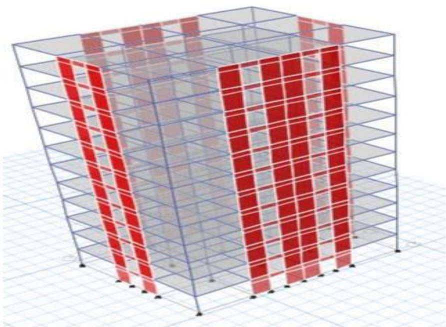

Fig. 18: 3D View of ICSW in XY Direction (M9)

RESULTS AND DISCUSSION:

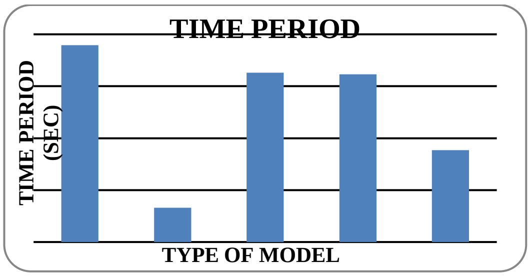

Fig. 19: Time period for SW

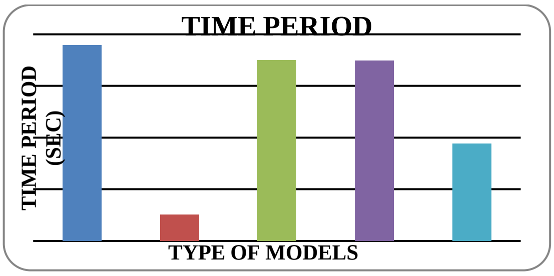

Fig. 20: Time period for CSW

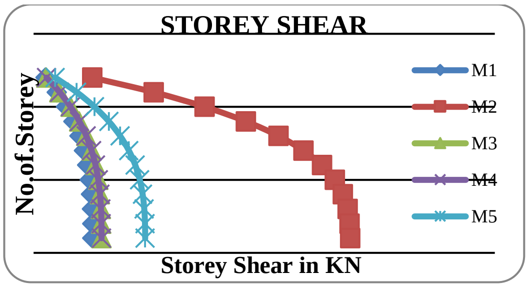

Fig. 21: Storey shear for SW

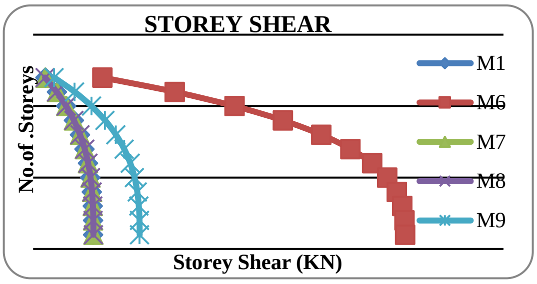

Fig. 22: Storey shear for CSW

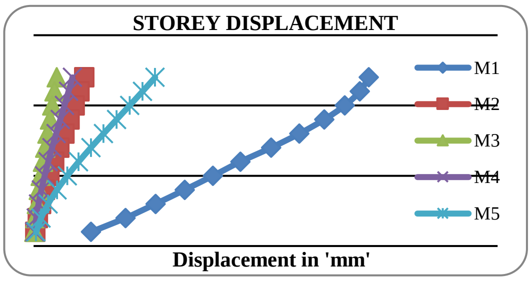

Fig. 23: Storey displacement for SW

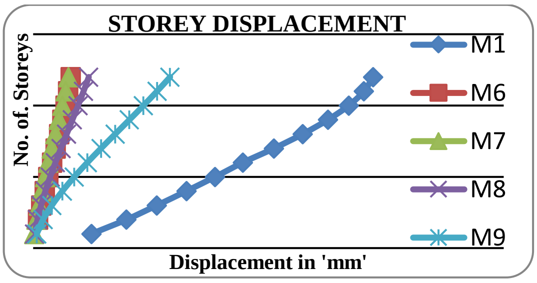

Fig. 24: Storey displacement for CSW

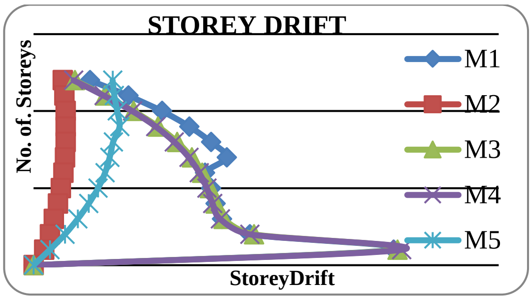

Fig. 25: Storey drift for SW

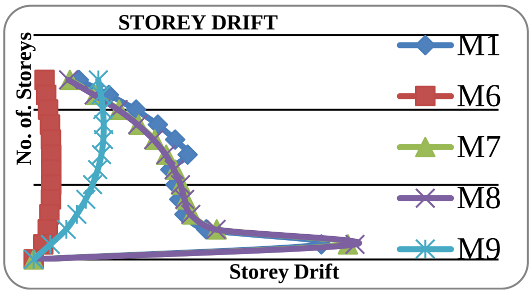

Fig. 26: Storey drift for CSW

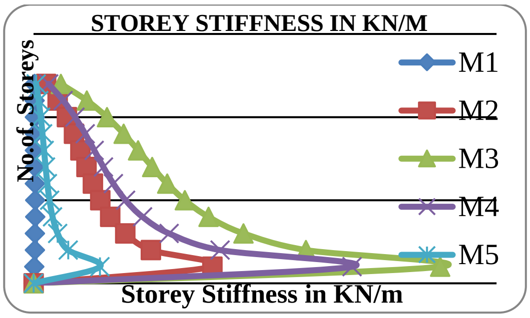

Fig. 27: Storey stiffness for SW

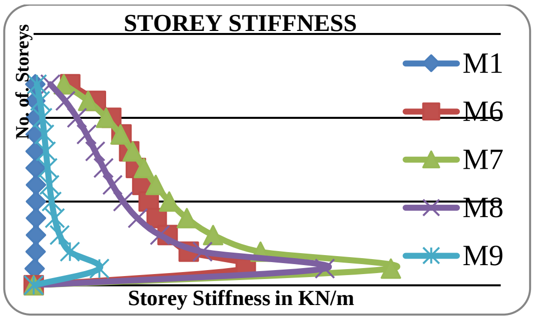

Fig. 28: Storey stiffness for CSW

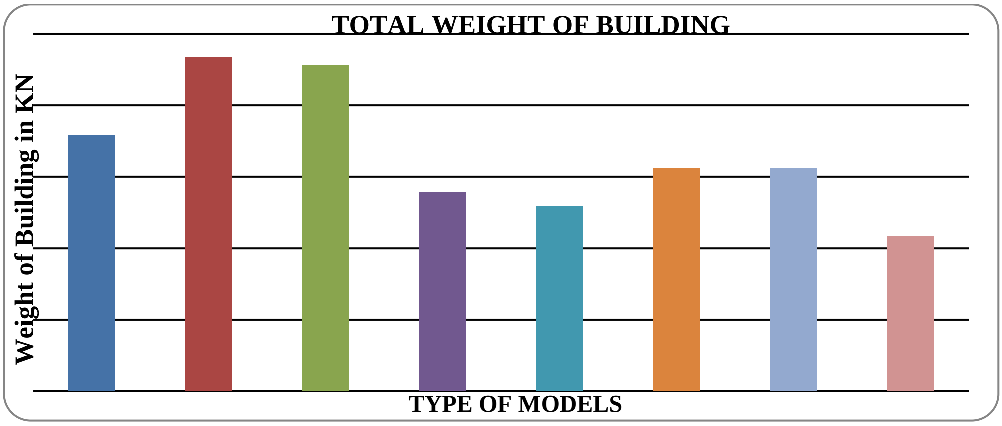

Fig. 28: Total Weight of Building.

CONCLUSION:

This research proposed the study various parameters like time period, storey shear, storey displacement, storey drift, storey stiffness and weight of building structures modelled as shear wall and coupled shear buildings. The following conclusions are drawn based on the studies carried out.

1. Coupled shear wall structures shows better performance in high rise1buildings due to its structural1efficiency when subjected to lateral load, provided with extra open spaces for doors, windows and elevators.
2. The Time period for models with Shear wall and Coupled Shear wall structure decreases when compared to Conventional frame structure. The model M6, that is position of coupled shear wall all around with opening shows 86.75% decrease in time period compared to conventional frame structures. As Time period decreases frequency increases and the stiffness of building increases.
3. The Storey shear increases for coupled shear wall and shear wall structures compared to conventional frame structure. At the base, model M2 that is position of shear wall all around with opening and model M6, that is position of coupled shear wall all around with opening shows base shear of 10269.80 kN and 11867.20 kN respectively. The Storey drift of Shear wall and Coupled Shear wall structures are within the permissible limit. The model M6 was found to be maximum percentage reduction of storey drift that is 76.18% compared to conventional frame.
4. The model M7 that is position of coupled shear wall along X direction shows 89.53% reduction in Storey displacement when compared to conventional frame structure. The Storey stiffness of Shear wall and Coupled

Shear wall structures was considerably increased. The position of shear wall and Coupled shear wall in X direction that is M3 and M7 shows 99.8% and 99.5% increased when compared to Conventional structure.

5. All the Coupled Shear wall structures shows reduced weight compare to Shear wall structures, out of which the position of Coupled shear wall in intermediate X and Y direction shows more weight difference compared to shear wall structures.
6. By the Parametric Study it has been observed that the Coupled Shear wall Shows marginal difference with respect to Solid Shear Wall considering all parameters and they are used in construction of high rise structures.

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