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Performance Evaluation of Shear Framed Multi-Storey Structure using Diagonal Strut at Different Locations

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Abstract: Shear frame system is a structural engineering system that is used in sky scraper structures, enabling them to resist lateral load from wind and seismic pressures. Shear frame structural system consists of diagonal strut construct to resist the lateral loads. Shear framed system is simplest form of system. This system is reasonably efficient for structure having storey more than 25. With the advent of new and improved methods, the significant role of diagonal strut on overall structure's seismic response has been established. The aim of present research work is to investigate the effect of diagonal strut in multi – storey structure considering shear frame system with different geometry to with stand under similar seismic parameters. In this research work, reinforced concrete shear framed structure (column spacing 3m) with G+25, G+30, G+35 and G+40 storey, with different position of diagonal strut are taken into analysis. Structures have been analysed in STAAD Pro. V8i software. The building is analysed by ESM for zone 3. Various parameters such as lateral displacement, storey shear, storey drift, base shear and storey stiffness are determined and comparison of various parameters are made for G+25, G+30, G+35 and G+40 structure.
Keywords: Shear framed system, Equivalent diagonal strut, Single diagonal strut, Cross diagonal strut, Tall buildings

I. INTRODUCTION

Structure is subjected to various types of loads during its service life. Wind and earthquake loads are lateral loads; those play an important role in structural design. Many technologies and materials are developed to reduce the effect of earthquake and wind load and make structure safe. These materials provide the strength to structures but applicable for limited height of structure. As the height increases, the rigidity and stability are required. For the rigidity and stability, many structural systems are developed. S. Vijaya Bhaskar Reddy et. al. (2018) – In this research work, shear wall system and framed tube system are designed for 30, 40, 50, 60 storey structures. The analysis has been carried out using STAAD PRO 2005. The roof displacement, internal forces (support reaction, bending moments and shear forces) of members and joint displacement are studied and compared. It is seen that the shear wall system is very must effective in resisting lateral loads for structures up to 30 stories and for structures beyond 30 stories frame tube system is very much effective than shear wall system in resisting lateral loads. Pooja Desai et. al. (2017) – This paper summarizes the seismic behaviour of four structures with 5, 10, 15 and 20 storey and plan dimension of 25m x 15m. These structures are analysed using equivalent static load method and response spectrum method in ETABS. It concluded that braces increase lateral stiffness of structure. Due to the increase in stiffness, the lateral deformation of the structure is reduced compared wrt bare frame. The braces act as axially loaded members (truss members) when subject to lateral seismic forces. As such the brace members are more effective in carrying lateral forces than frame members. Due to the increase in stiffness, braced structure is subjected to large base shear as compared to bare frame and the shear demand on columns is also increased. Nikhil Agarwal et. al. (2013) – Masonry infilled RC frame with and without opening including soft storey were analysed by using equivalent diagonal strut method. In this research work, a symmetrical frame of college building (G+5) located in seismic zone – III was considered by modelling of initial frame. According to FEMA – 273 and ATC – 40 which contain provisions of calculation of stiffness of infilled frames by modelling infill as "ESM". This analysis is to be carried out on models such as bare frame, strut frame and strut frame with 15% centre and corner opening, which is performed by using STAAD PRO. From analysis, it was concluded that infill panels increase the stiffness of the structure. From results they reported that infill panels increase stiffness of structure and deflection at centre opening is more than the corner opening. Because of infill wall effect, there is drastic decrease in value of axial force in column. The increase in opening percentage leads to a decrease on lateral stiffness of infilled frame. CVR Murthy at. al. (2004) – In this study, it is observed that strength and stiffness of structure is increased by providing infills. Drift and ductility of structure is reduced by providing infills. Building is designed by equivalent braced frame method and it is observed that it gives better performance. They concluded that the effect of brick infills on seismic performance need to be well understood and based on that, design methodologies, which exploit the benefits of infills in a rational manner, need to be developed.

II. ANALYTICAL MODELLING

In this work, systematic analysis is done for G+25, G+30, G+35 and G+40 storey structures. Analysis of these structures are carried out by using STAAD PRO. V8i software. In this study, structures are designed for zone – III. The structures are analysed by using ESM. Mathematical modelling for infill wall is done according to IS 1893 (P-1) – 2016.

Diagonal strut has been provided in two ways for the study:
1) *Single Diagonal Strut (SDS):* Only single diagonal member has been used to resist lateral load and hence it is termed as single diagonal strut.
2) *Cross Diagonal Strut (CDS):* Two diagonal members crossing each other has been used to resist lateral load and hence it is termed as cross diagonal strut.

Following cases has taken into consideration –
a) *Case T* – Shear frame without considering effect of infill
b) *Case S1* – Shear frame with SDS provided at outer corners
c) *Case S2* – Shear frame with SDS provided at outer corners with middle bay
d) *Case S3* – Shear frame with diagonal strut provided at centre of structure (as core)
e) *Case S4* – Shear frame with diagonal strut provided at outer corners with middle by and at centre of structure as core
f) *Case C1* – Shear frame with CDS provided at outer corners
g) *Case C2* – Shear frame with CDS provided at outer corners with middle bay
h) *Case C3* – Shear frame with diagonal strut provided at centre of structure (as core)
i) *Case C4* – Shear frame with diagonal strut provided at outer corners with middle bay and at centre of structure as core

A. Geometry of Structure

Plan of structure – 21m x 21m
Height of each storey – 3m
Distance between two columns – 3 m

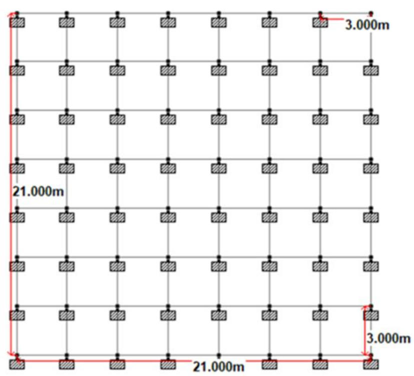

Fig. 1 Plan of G+25/30/35/40 storey structures

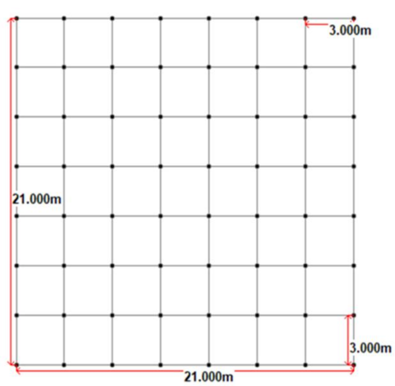

Fig. 2 Plan of Case T

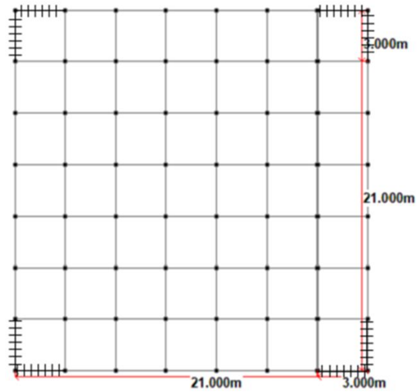

Fig. 3 Plan of Case S1 and Case C1

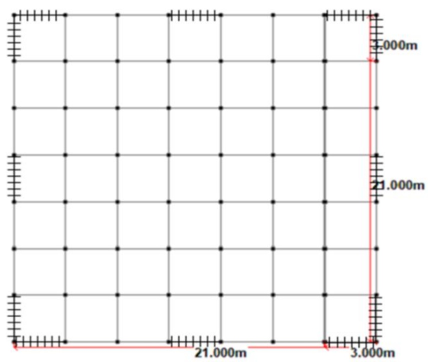

Fig. 4 Plan of Case S2 and Case C2

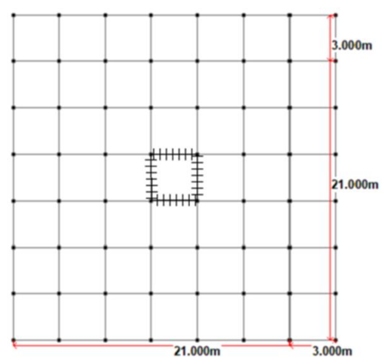

Fig. 5 Plan of Case S3 and Case C3

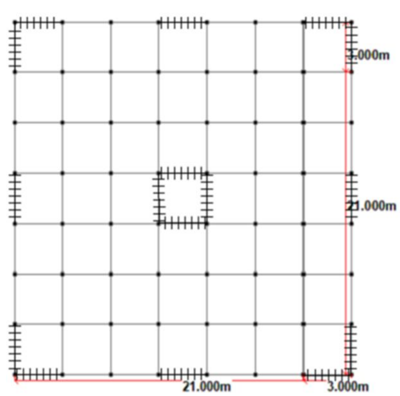

Fig. 6 Plan of Case S4 and Case C4

B. Structure Properties

The following properties are considered in analysis of structures –

Table I
Site Properties For Structure

Details of building	G+25,30,35,40
Wall Thickness 1. Outer wall thickness 2. Inner wall thickness 3. Parapet wall thickness	 230mm 115mm 230mm
Depth of foundation	1.5m
Storey Height	3m
Total height of building (m)	79.5, 94.5, 109.5, 124.5

Table II
Seismic Properties Of Structures

Particulars	Value
Seismic zone	III
Zone factor	0.16
Importance factor	1.5
Response reduction factor	5
Soil condition	Medium
Damping	5%

C. Size of Members

The dimensions of different structural members are followed –

Table III
Dimensions of structural members

Member Name	Dimensions
Beam	300mm X 230mm
Column	350mm X 350mm
Slab	150mm
Diagonal Strut	
1. For inner wall	115 mm X 422.658 mm
2. For outer wall	230 mm X 452.994 mm

D. Loading on Structure

The following loading are applied on the structure for the analysis –

Table IV
Loading on structures

Type of Load	Intensity of load
Dead load	
1. Self-weight	
2. Wall load i. Outer wall load ii. Inner wall load iii. Parapet wall load on roof	 12.42 kN/m 6.21 kN/m 4.6 kN/m
3. Floor load	3.75 kN/m
Live load 1. Live load on floors 2. Live load on roof	 3 kN/m^2 1.5 kN/m^2

E. Properties of Brick Masonry

The following properties of brick masonry has considered while analysing structures –

Table V
Properties of brick masonry

Properties	Value
Young's Modulus (E)	2457.037 N/mm^2
Poisson's Ratio (nu)	0.2
Density	20 kN/m^3
Critical Damping	5%
Shear Modulus (G)	1023.765 N/mm^2

F. Load Combination for Analysis

The following load combinations are considered in analysis of structure –
1.5(DL+LL)
1.2(DL+LL±EQ-X)
1.2(DL+LL±EQ-Z)
1.5(DL±EQ-X)
1.5(DL±EQ-Z)
0.9DL±1.5EQ-X 15
0.9DL±1.5EQ-Z

III. RESULTS

The analysis of structures is done by STAAD Pro. V8i using IS 1893 (Part – 1): 2002. From the seismic analysis results obtained are given as below:

A. Results of Lateral Displacement of Different Storey Structure for Different Cases

From seismic analysis results obtained are tabulated in Table VI and Table VII for single diagonal strut and cross diagonal strut for different storey structures for different case respectively.

Table VI
Results of lateral displacement of different storey structure with SDS

Structural Cases	Lateral displacement (mm) at							
	BS – G+25	TS – G+25	BS – G+30	TS – G+30	BS – G+35	TS – G+35	BS – G+40	TS – G+40
T	16.18	379.85	16.91	496.95	17.56	631.91	18.17	787.39
S1	13.52	352.88	14.17	467.71	14.77	600.69	15.33	754.48
S2	12.52	325.71	13.11	433.43	13.64	558.92	14.13	704.88
S3	15.38	356.77	16.07	468.41	16.70	597.67	17.28	747.21
S4	11.85	309.56	12.43	414.13	12.92	533.80	13.38	675.01

Note – BS – base storey, TS – top storey

From Table VI, it is found in case T that the G+25, G+30, G+35 and G+40 storey structures achieved lateral displacement is 379.85 mm, 469.95 mm, 631.91 mm and 787.39 mm respectively at top storey. For the controlling of lateral displacement of structure, the single diagonal strut has provided at different locations of structure. After the providing single diagonal strut at different locations in G+25 storey structures, it has found in case S1, case S2, case S3 and case S4 that the lateral displacement has decreased to 352.88 mm, 325.71 mm, 356.77 mm and 309.56 mm respectively at top storey. Accordingly, from the analysis of different cases of G+30 storey structures, the lateral displacement has decreased to 467.71 mm, 433.43 mm, 468.41 mm and 414.13 mm in case S1, case S2, case S3 and case S4 respectively at top storey. Another structure has analysed and from the analysis of different cases of G+35 storey structures, it has observed that the lateral displacement has decreased to 600.69 mm, 558.92 mm, 597.67 mm and 533.80 mm in case S1, case S2, case S3 and case S4 respectively at top storey.

Yet another structure has analysed and from the analysis of different cases of G+40 storey structures, it has observed that the lateral displacement has decreased to 754.48 mm, 704.88 mm, 747.21 mm and 675.01 mm in case S1, case S2, case S3 and case S4 respectively at top storey.

Table VII
Results Of Lateral Displacement Of Different Storey Structure With CDS

Structural Cases	Lateral displacement (mm) at							
	BS – G+25	TS – G+25	BS – G+30	TS – G+30	BS – G+35	TS – G+35	BS – G+40	TS – G+40
T	16.18	379.85	16.91	496.95	17.56	631.91	18.17	787.39
C1	12.39	345.48	13.01	459.64	13.56	591.94	14.06	745.03
C2	11.11	316.74	11.67	423.70	12.17	548.50	12.64	693.84
C3	14.45	349.91	15.11	460.49	15.71	588.70	16.27	737.23
C4	10.41	297.39	11.00	402.80	11.43	518.94	11.87	658.92

Note – BS – base storey, TS – top storey

From Table VII, it is found in case T that the G+25, G+30, G+35 and G+40 storey structures achieved lateral displacement is 379.85 mm, 469.95 mm, 631.91 mm and 787.39 mm respectively at top storey. For the controlling of lateral displacement of structure, the cross – diagonal strut has provided at different locations of structure.

After the providing cross – diagonal strut at different locations in G+25 storey structures, it has found in case S1, case S2, case S3 and case S4 that the lateral displacement has decreased to 345.48 mm, 316.74 mm, 349.91 mm and 297.39 mm respectively at top storey. Accordingly, from the analysis of different cases of G+30 storey structures, the lateral displacement has decreased to 459.64 mm, 423.70 mm, 460.49 mm and 402.80 mm in case S1, case S2, case S3 and case S4 respectively at top storey.

Another structure has analysed and from the analysis of different cases of G+35 storey structures, it has observed that the lateral displacement has decreased to 591.94 mm, 548.50 mm, 588.70 mm and 518.94 mm in case S1, case S2, case S3 and case S4 respectively at top storey. Yet another structure has analysed and from the analysis of different cases of G+40 storey structures, it has observed that the lateral displacement has decreased to 745.03 mm, 693.84 mm, 737.23 mm and 658.92 mm in case S1, case S2, case S3 and case S4 respectively at top storey.

B. Results of Storey drift of Different Storey Structure for Different Cases

From seismic analysis results obtained are tabulated in Table VIII and Table IX for single diagonal strut and cross diagonal strut for different storey structures for different case respectively.

Table VIII
Results of Storey Drift of Different Storey Structure with SDS

Structural Cases	Storey drift (mm) at							
	BS – G+25	TS – G+25	BS – G+30	TS – G+30	BS – G+35	TS – G+35	BS – G+40	TS – G+40
T	16.18	4.35	16.91	5.37	17.56	6.64	18.17	8.16
S1	13.52	6.83	14.17	7.82	14.77	9.02	15.33	10.48
S2	12.52	6.07	13.11	7.44	13.64	8.68	14.13	10.11
S3	15.38	4.55	16.07	5.57	16.70	6.82	17.28	8.32
S4	11.85	6.05	12.43	7.22	12.92	8.41	13.38	9.84

Note – BS – base storey, TS – top storey

From Table VIII, it is found in case T that the G+25, G+30, G+35 and G+40 storey structures achieved storey drift is 4.35 mm, 5.37 mm, 6.64 mm and 8.16 mm respectively at top storey. For the improving of storey drift of structure, the single diagonal strut has provided at different locations of structure. After the providing single diagonal strut at different locations in G+25 storey structures, it has found in case S1, case S2, case S3 and case S4 that the storey drift has increased to 6.83 mm, 6.07 mm, 4.55 mm and 6.05 mm respectively at top storey. Accordingly, from the analysis of different cases of G+30 storey structures, the storey drift has increased to 7.82 mm, 7.44 mm, 5.57 mm and 7.22 mm in case S1, case S2, case S3 and case S4 respectively at top storey.

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Another structure has analysed and from the analysis of different cases of G+35 storey structures, it has observed that the storey drift has increased to 9.02 mm, 8.68 mm, 6.82 mm and 8.41 mm in case S1, case S2, case S3 and case S4 respectively at top storey. Yet another structure has analysed and from the analysis of different cases of G+40 storey structures, it has observed that the storey drift has increased to 10.48 mm, 10.11 mm, 8.32 mm and 9.84 mm in case S1, case S2, case S3 and case S4 respectively at top storey.

Table IX
Results of Storey Drift of Different Storey Structure with CDS

Structural Cases	Storey drift (mm) at							
	BS – G+25	TS – G+25	BS – G+30	TS – G+30	BS – G+35	TS – G+35	BS – G+40	TS – G+40
T	16.18	4.35	16.91	5.37	17.56	6.64	18.17	8.16
C1	12.39	7.63	13.01	8.54	13.56	9.68	14.06	11.08
C2	11.11	6.70	11.67	8.04	12.17	9.29	12.64	10.74
C3	14.45	5.07	15.11	6.05	15.71	7.25	16.27	8.72
C4	10.41	6.68	11.00	7.92	11.43	8.99	11.87	10.41

Note – BS – base storey, TS – top storey

From Table IX, it is found in case T that the G+25, G+30, G+35 and G+40 storey structures achieved storey drift is 4.35 mm, 5.37 mm, 6.64 mm and 8.16 mm respectively at top storey. For the improving of storey drift of structure, the cross – diagonal strut has provided at different locations of structure.

After the providing cross – diagonal strut at different locations in G+25 storey structures, it has found in case S1, case S2, case S3 and case S4 that the storey drift has increased to 7.63 mm, 6.70 mm, 5.07 mm and 6.68 mm respectively at top storey. Accordingly, from the analysis of different cases of G+30 storey structures, the storey drift has increased to 8.54 mm, 8.04 mm, 6.05 mm and 7.92 mm in case S1, case S2, case S3 and case S4 respectively at top storey.

Another structure has analysed and from the analysis of different cases of G+35 storey structures, it has observed that the storey drift has increased to 9.68 mm, 9.29 mm, 7.25 mm and 8.99 mm in case S1, case S2, case S3 and case S4 respectively at top storey. Yet another structure has analysed and from the analysis of different cases of G+40 storey structures, it has observed that the storey drift has increased to 11.08 mm, 10.74 mm, 8.72 mm and 10.41 mm in case S1, case S2, case S3 and case S4 respectively at top storey.

C. Results of Storey Shear of Different storey structure for Different Cases

From seismic analysis results obtained are tabulated in Table X and Table XI for single diagonal strut and cross diagonal strut for different storey structures for different case respectively.

Table X
Results of Storey Shear of Different Storey Structure with SDS

Structural Cases	Storey shear (kN) at							
	BS – G+25	TS – G+25	BS – G+30	TS – G+30	BS – G+35	TS – G+35	BS – G+40	TS – G+40
T	1.003	150.24	0.622	131.72	0.415	117.77	0.290	106.87
S1	1.014	151.84	0.629	133.13	0.419	119.04	0.294	108.03
S2	1.019	152.65	0.632	133.84	0.421	119.67	0.296	108.60
S3	1.006	150.67	0.624	132.09	0.416	118.11	0.291	107.18
S4	1.022	153.08	0.633	134.05	0.422	120.01	0.297	108.91

Note – BS – base storey, TS – top storey

From Table X, it is found in case T that the G+25, G+30, G+35 and G+40 storey structures achieved storey shear is 150.24 kN, 131.72 kN, 117.77 kN and 106.87 kN respectively at top storey. For the controlling of lateral displacement of structure, the single – diagonal strut has provided at different locations of structure.

After the providing single – diagonal strut at different locations in G+25 storey structures, it has found in case S1, case S2, case S3 and case S4 that the storey shear has increased to 151.84 kN, 152.65 kN, 150.67 kN and 153.08 kN respectively at top storey. Accordingly, from the analysis of different cases of G+30 storey structures, the storey shear has increased to 133.13 kN, 133.84 kN, 132.09 kN and 134.05 kN mm in case S1, case S2, case S3 and case S4 respectively at top storey.

Another structure has analysed and from the analysis of different cases of G+35 storey structures, it has observed that the storey shear has increased to 119.04 kN, 119.67 kN, 118.11 kN and 120.01 kN in case S1, case S2, case S3 and case S4 respectively at top storey. Yet another structure has analysed and from the analysis of different cases of G+40 storey structures, it has observed that the storey shear has increased to 108.03 kN, 108.60 kN, 107.18 kN and 108.91 kN in case S1, case S2, case S3 and case S4 respectively at top storey.

Table XI
Results Of Storey Shear Of Different Storey Structure With Cds

Structural Cases	Storey shear (kN) at							
	BS – G+25	TS – G+25	BS – G+30	TS – G+30	BS – G+35	TS – G+35	BS – G+40	TS – G+40
T	1.003	150.24	0.622	131.72	0.415	117.77	0.290	106.87
C1	1.024	153.45	0.636	134.55	0.423	120.30	0.297	109.18
C2	1.036	155.06	0.643	135.96	0.428	121.57	0.300	110.33
C3	1.008	151.09	0.626	132.48	0.417	118.45	0.293	107.49
C4	1.041	155.92	0.646	136.55	0.430	122.25	0.302	110.95

Note – BS – base storey, TS – top storey

From Table XI, it is found in case T that the G+25, G+30, G+35 and G+40 storey structures achieved storey shear is 150.24 kN, 131.72 kN, 117.77 kN and 106.87 kN respectively at top storey. For the controlling of lateral displacement of structure, the cross – diagonal strut has provided at different locations of structure.

After the providing cross – diagonal strut at different locations in G+25 storey structures, it has found in case S1, case S2, case S3 and case S4 that the storey shear has increased to 153.45 kN, 155.06 kN, 151.09 kN and 155.92 kN respectively at top storey. Accordingly, from the analysis of different cases of G+30 storey structures, the storey shear has increased to 134.55 kN, 135.96 kN, 132.48 kN and 136.55 kN mm in case S1, case S2, case S3 and case S4 respectively at top storey.

Another structure has analysed and from the analysis of different cases of G+35 storey structures, it has observed that the storey shear has increased to 120.30 kN, 121.57 kN, 118.45 kN and 122.25 kN in case S1, case S2, case S3 and case S4 respectively at top storey. Yet another structure has analysed and from the analysis of different cases of G+40 storey structures, it has observed that the storey shear has increased to 109.18 kN, 110.33 kN, 107.49 kN and 110.95 kN in case S1, case S2, case S3 and case S4 respectively at top storey.

D. Results of Base Shear of Different Storey structure for Different Cases

From seismic analysis results obtained are tabulated in Table XII and Table XIII for single diagonal strut and cross diagonal strut for different storey structures for different case respectively.

Table XII
Results of Base Shear of Different Storey Structure with SDS

Structural Cases	Base shear (kN) at							
	BS – G+25	TS – G+25	BS – G+30	TS – G+30	BS – G+35	TS – G+35	BS – G+40	TS – G+40
T	2505.2	150.24	2608.8	131.72	2701.4	117.77	2786.1	106.87
S1	2533.7	151.84	2638.5	133.13	2732.2	119.04	2818.0	108.03
S2	2547.9	152.65	2653.4	133.84	2747.6	119.67	2833.9	108.60
S3	2512.8	150.67	2616.8	132.09	2709.6	118.11	2794.7	107.18
S4	2555.5	153.08	2657.8	134.05	2755.9	120.01	2842.5	108.91

Note – BS – base storey, TS – top storey

From Table XII, it is found in case T that the G+25, G+30, G+35 and G+40 storey structures achieved base shear is 2505.2 kN, 2608.8 kN, 2701.4 kN and 2786.1 kN respectively at bottom storey. For the controlling of performance of structure, the single – diagonal strut has provided at different locations of structure.

After the providing single – diagonal strut at different locations in G+25 storey structures, it has found in case S1, case S2, case S3 and case S4 that the base shear has increased to 2533.7 kN, 2547.9 kN, 2512.8 kN and 2555.5 kN respectively at bottom storey. Accordingly, from the analysis of different cases of G+30 storey structures, the base shear has increased to 2638.5 kN, 2653.4 kN, 2616.8 kN and 2657.8 kN mm in case S1, case S2, case S3 and case S4 respectively at bottom storey.

Another structure has analysed and from the analysis of different cases of G+35 storey structures, it has observed that the base shear has increased to 2732.2 kN, 2747.6 kN, 2709.6 kN and 2755.9 kN in case S1, case S2, case S3 and case S4 respectively at bottom storey. Yet another structure has analysed and from the analysis of different cases of G+40 storey structures, it has observed that the base shear has increased to 2818.0 kN, 2833.9 kN, 2794.7 kN and 2842.5 kN in case S1, case S2, case S3 and case S4 respectively at bottom storey.

Table XIII

Results of Base Shear of Different Storey Structure with CDS

Structural Cases	Base shear (kN) at							
	BS – G+25	TS – G+25	BS – G+30	TS – G+30	BS – G+35	TS – G+35	BS – G+40	TS – G+40
T	2505.2	150.24	2608.8	131.72	2701.4	117.77	2786.1	106.87
C1	2562.1	153.45	2668.3	134.55	2763.1	120.30	2849.9	109.18
C2	2590.6	155.06	2697.9	135.96	2793.9	121.57	2991.8	110.33
C3	2520.5	151.09	2624.7	132.48	2717.9	118.45	2803.2	107.49
C4	2605.8	155.92	2710.3	136.55	2810.5	122.25	2898.9	110.95

Note – BS – base storey, TS – top storey

From Table XIII, it is found in case T that the G+25, G+30, G+35 and G+40 storey structures achieved base shear is 2505.2 kN, 2608.8 kN, 2701.4 kN and 2786.1 kN respectively at bottom storey. For the controlling of performance of structure, the cross – diagonal strut has provided at different locations of structure.

After the providing cross – diagonal strut at different locations in G+25 storey structures, it has found in case S1, case S2, case S3 and case S4 that the base shear has increased to 2562.1 kN, 2590.6 kN, 2520.5 kN and 2605.8 kN respectively at bottom storey. Accordingly, from the analysis of different cases of G+30 storey structures, the base shear has increased to 2668.3 kN, 2697.9 kN, 2624.7 kN and 2710.3 kN mm in case S1, case S2, case S3 and case S4 respectively at bottom storey.

Another structure has analysed and from the analysis of different cases of G+35 storey structures, it has observed that the base shear has increased to 2763.1 kN, 2793.9 kN, 2717.9 kN and 2810.5 kN in case S1, case S2, case S3 and case S4 respectively at bottom storey. Yet another structure has analysed and from the analysis of different cases of G+40 storey structures, it has observed that the base shear has increased to 2849.9 kN, 2991.8 kN, 2803.2 kN and 2898.9 kN in case S1, case S2, case S3 and case S4 respectively at bottom storey.

E. Results of Storey Stiffness of Different Storey Structure for Different Cases

From seismic analysis results obtained are tabulated in Table XIV and Table XV for single diagonal strut and cross diagonal strut for different storey structures for different case respectively.

Table XIV

Results of Storey Stiffness of Different Storey Structure with SDS

Structural Cases	Storey stiffness (kN/mm) at							
	BS – G+25	TS – G+25	BS – G+30	TS – G+30	BS – G+35	TS – G+35	BS – G+40	TS – G+40
T	0.0620	34.553	0.0368	24.519	0.0236	17.736	0.0154	13.096
S1	0.0750	22.225	0.0444	17.031	0.0284	13.191	0.0184	10.311
S2	0.0814	25.152	0.0482	17.994	0.0309	13.792	0.0211	10.738
S3	0.0654	33.099	0.0388	23.724	0.0249	17.318	0.0171	12.878
S4	0.0862	25.289	0.0509	18.566	0.0327	14.277	0.0224	11.064

Note – BS – base storey, TS – top storey

From Table XIV, it is found in case T that the G+25, G+30, G+35 and G+40 storey structures achieved storey stiffness is 34.553 kN/mm, 24.519 kN/mm, 17.736 kN/mm and 13.096 kN/mm respectively at top storey. For improving the performance of structure, the single – diagonal strut has provided at different locations of structure.

After the providing single – diagonal strut at different locations in G+25 storey structures, it has found in case S1, case S2, case S3 and case S4 that the storey stiffness has decreased to 22.225 kN/mm, 25.152 kN/mm, 33.099 kN/mm and 25.289 kN/mm respectively at top storey. Accordingly, from the analysis of different cases of G+30 storey structures, the storey stiffness has decreased to 17.031 kN/mm, 17.994 kN/mm, 23.724 kN/mm and 18.566 kN/m mm in case S1, case S2, case S3 and case S4 respectively at top storey.

Another structure has analysed and from the analysis of different cases of G+35 storey structures, it has observed that the storey stiffness has decreased to 13.191 kN/mm, 13.792 kN/mm, 17.318 kN/mm and 14.277 kN/mm in case S1, case S2, case S3 and case S4 respectively at top storey. Yet another structure has analysed and from the analysis of different cases of G+40 storey structures, it has observed that the storey stiffness has decreased to 10.311 kN/mm, 10.738 kN/mm, 12.878 kN/mm and 11.064 kN/mm in case S1, case S2, case S3 and case S4 respectively at bottom storey.

Table XV
Results Of Storey Stiffness Of Different Storey Structure With CDS

Structural Cases	Storey stiffness (kN/mm) at							
	BS – G+25	TS – G+25	BS – G+30	TS – G+30	BS – G+35	TS – G+35	BS – G+40	TS – G+40
T	0.0620	34.553	0.0368	24.519	0.0236	17.736	0.0154	13.096
C1	0.0826	20.117	0.0489	15.757	0.0312	12.427	0.0201	9.855
C2	0.0933	23.139	0.0551	16.910	0.0352	13.082	0.0226	10.278
C3	0.0698	29.826	0.0414	21.900	0.0265	16.336	0.0178	12.329
C4	0.1000	23.324	0.0588	17.238	0.0376	13.603	0.0258	10.654

Note – BS – base storey, TS – top storey

From Table XV, it is found in case T that the G+25, G+30, G+35 and G+40 storey structures achieved storey stiffness is 34.553 kN/mm, 24.519 kN/mm, 17.736 kN/mm and 13.096 kN/mm respectively at top storey. For improving the performance of structure, the double – diagonal strut has provided at different locations of structure.

After the providing double – diagonal strut at different locations in G+25 storey structures, it has found in case S1, case S2, case S3 and case S4 that the storey stiffness has decreased to 20.117 kN/mm, 23.139 kN/mm, 29.826 kN/mm and 23.324 kN/mm respectively at top storey. Accordingly, from the analysis of different cases of G+30 storey structures, the storey stiffness has decreased to 15.757 kN/mm, 16.910 kN/mm, 21.900 kN/mm and 17.238 kN/mm in case S1, case S2, case S3 and case S4 respectively at top storey.

Another structure has analysed and from the analysis of different cases of G+35 storey structures, it has observed that the storey stiffness has decreased to 12.427 kN/mm, 13.082 kN/mm, 16.336 kN/mm and 13.603 kN/mm in case S1, case S2, case S3 and case S4 respectively at top storey. Yet another structure has analysed and from the analysis of different cases of G+40 storey structures, it has observed that the storey stiffness has decreased to 9.855 kN/mm, 10.278 kN/mm, 12.329 kN/mm and 10.654 kN/mm in case S1, case S2, case S3 and case S4 respectively at bottom storey.

IV. COMPARISON OF RESULTS

From the seismic analysis, following comparison of results of different structures are mapped:

A. Comparison Of Results Of Lateral Displacement Of Different Storey Structure For Different Cases

The comparison of analysed results of lateral displacement is done as per the providing the diagonal strut. The comparison of analysed results is shown graphically from Fig. 7 to Fig. 10 and Fig. 11 to Fig. 14 for single diagonal strut and cross – diagonal strut respectively.

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1) *With Single Diagonal Strut*

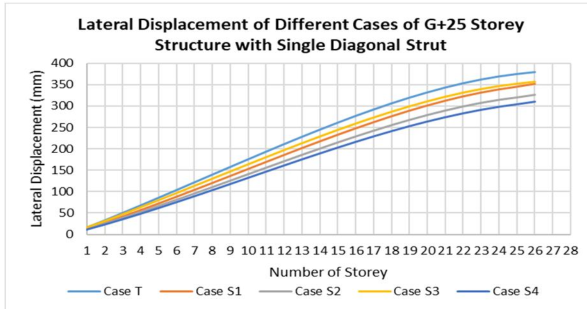

Fig.7 LD of G+25 of diff. cases with SDS

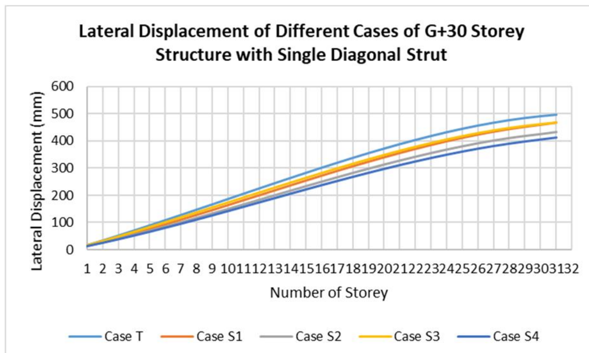

Fig.8 LD of G+30 of diff. cases with SDS

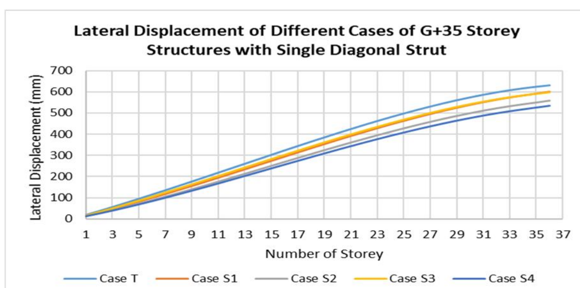

Fig.9 LD of G+35 of diff. cases with SDS

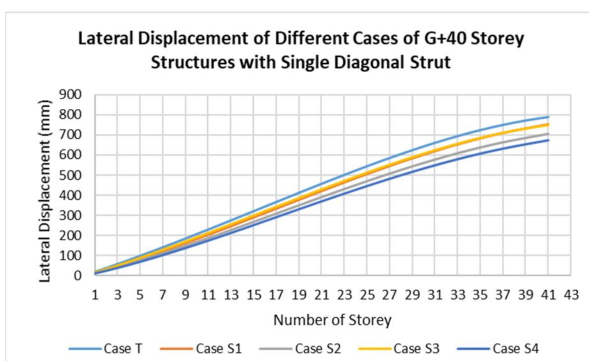

Fig.10 LD of G+40 of diff. cases with SDS

The comparison of analysed results of different cases with single – diagonal strut of G+25, G+30, G+35 and G+40 storey structure has shown in Fig. 7 to Fig. 10 respectively. From the study of figures, it has observed that case S4 of G+25, G+30, G+35 and G+40 that the lateral displacement has decreased by 18.51%, 16.67%, 15.53% and 14.27% respectively.

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2) With Cross Diagonal Strut

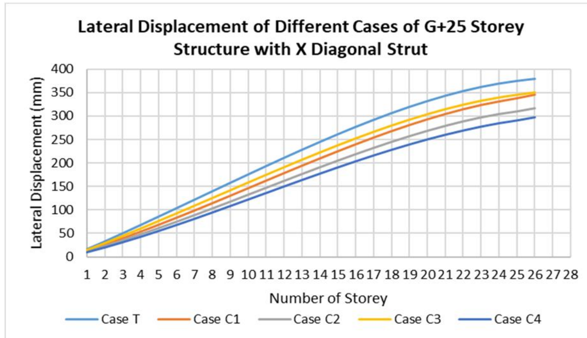

Fig.11 LD of G+25 of diff. cases with CDS

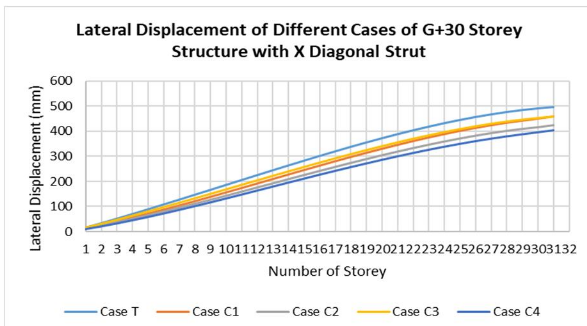

Fig.12 LD of G+30 of diff. cases with CDS

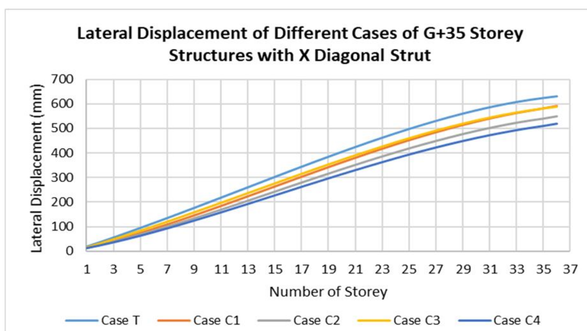

Fig.13 LD of G+35 of diff. cases with CDS

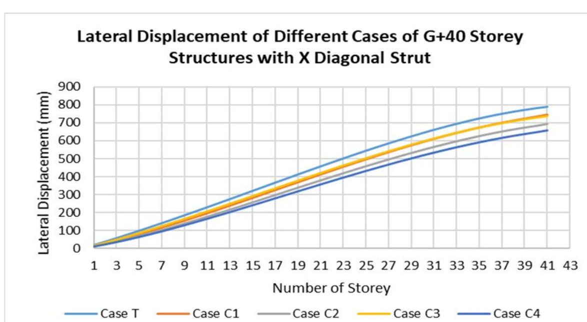

Fig.14 LD of G+40 of diff. cases with CDS

The comparison of analysed results of different cases with cross – diagonal strut of G+25, G+30, G+35 and G+40 storey structure has shown in Fig. 11 to Fig. 14 respectively. From the study of figures, it has observed that case S4 of G+25, G+30, G+35 and G+40 that the lateral displacement has decreased by 21.71%, 18.95%, 17.88% and 16.32% respectively.

B. Comparison Of Results Of Storey Drift Of Different Storey Structure For Different Cases

The comparison of analysed results of storey drift is done as per the providing the diagonal strut. The comparison of analysed results is shown graphically from Fig. 15 to Fig. 18 and Fig. 19 to Fig. 22 for single diagonal strut and cross – diagonal strut respectively.

1) With Single Diagonal Strut

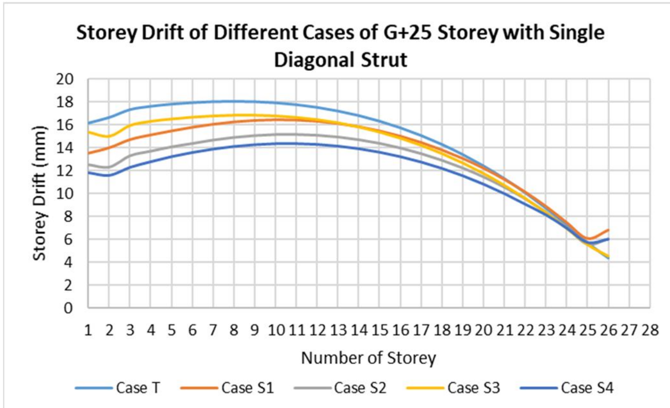

Fig.15 SD of G+25 of diff. cases with SDS

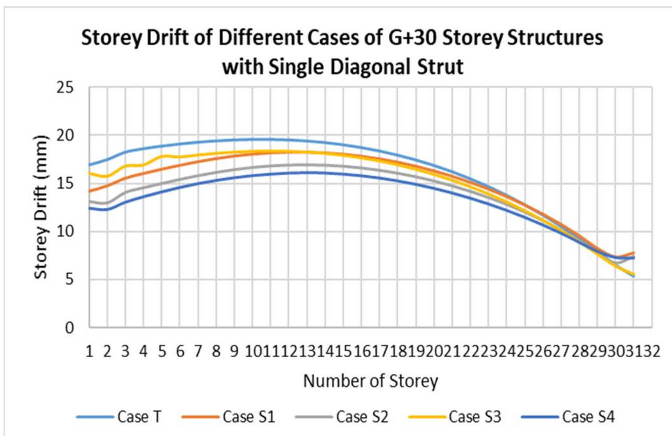

Fig.16 SD of G+30 of diff. cases with SDS

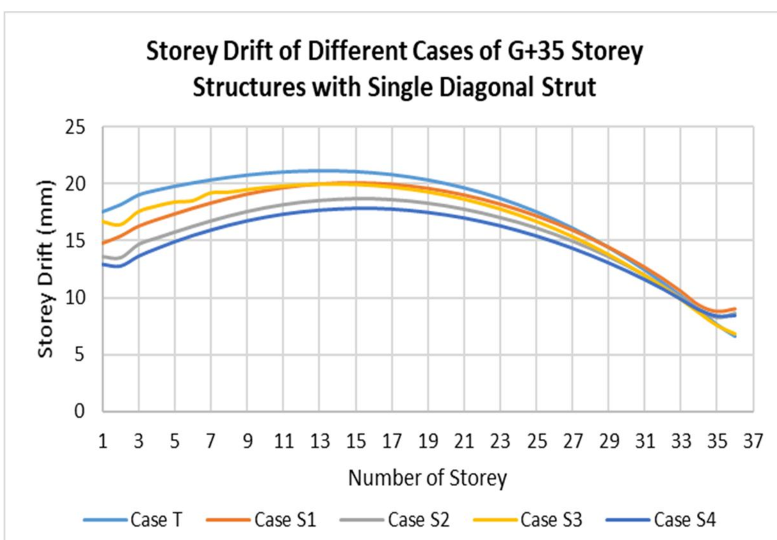

Fig.17 SD of G+35 of diff. cases with SDS

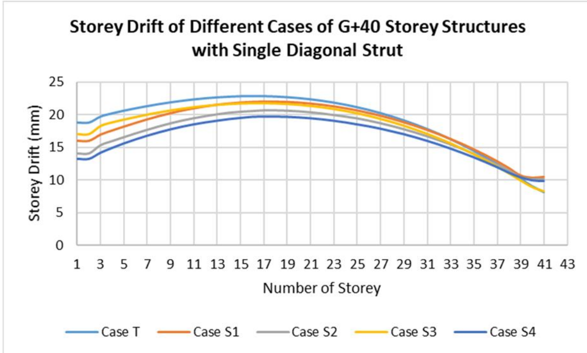

Fig.18 – SD of G+40 of diff. cases with SDS

The comparison of analysed results of different cases with single – diagonal strut of G+25, G+30, G+35 and G+40 storey structure has shown in Fig. 15 to Fig. 18 respectively. From the study of figures, it has observed that case S4 of G+25, G+30, G+35 and G+40 that the storey drift has increased by 39.21%, 34.40%, 26.60% and 20.62% respectively.

2) With Cross Diagonal Strut

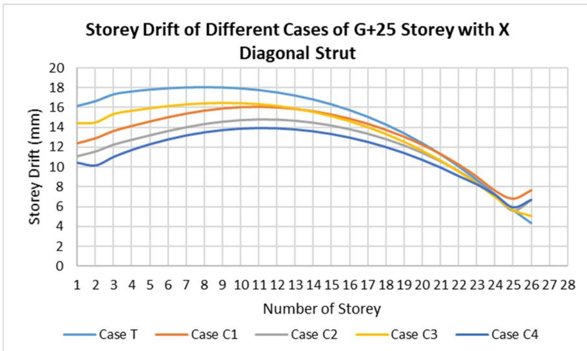

Fig.19 SD of G+25 of diff. cases with CDS

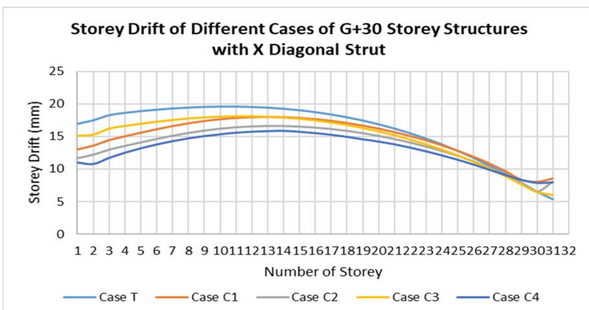

Fig.20 – SD of G+30 of diff. cases with CDS

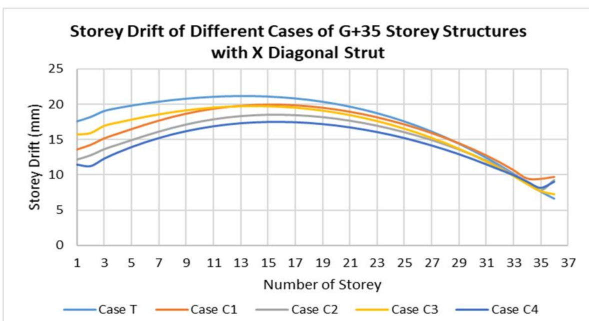

Fig.21 SD of G+35 of diff. cases with CDS

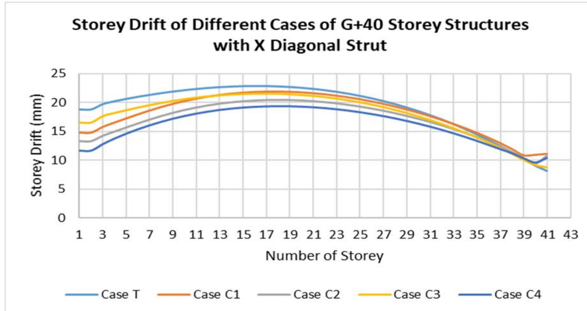

Fig.22 SD of G+40 of diff. cases with CDS

The comparison of analysed results of different cases with cross – diagonal strut of G+25, G+30, G+35 and G+40 storey structure has shown in Fig. 19 to Fig. 22 respectively. From the study of figures, it has observed that case S4 of G+25, G+30, G+35 and G+40 that the storey drift has increased by 53.75%, 47.45%, 35.35% and 27.61% respectively.

C. Comparison Of Results Of Storey Shear Of Different Storey Structure For Different Cases

The comparison of analysed results of storey shear is done as per the providing the diagonal strut. The comparison of analysed results is shown graphically from Fig. 23 to Fig. 26 and Fig. 27 to Fig. 30 for single diagonal strut and cross – diagonal strut respectively.

1) With Single Diagonal Strut

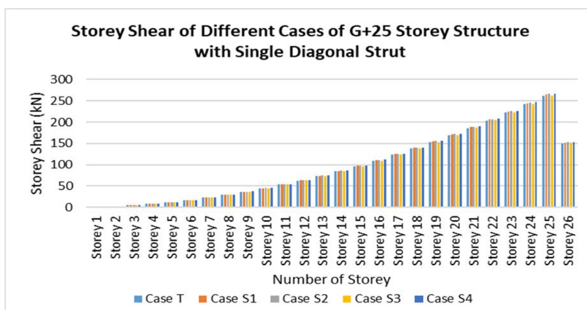

Fig.23 SS of G+25 of diff. cases with SDS

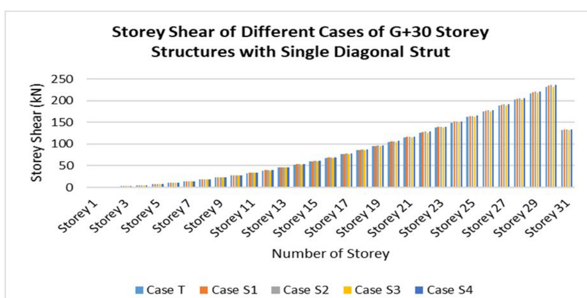

Fig.24 SS of G+30 of diff. cases with SDS

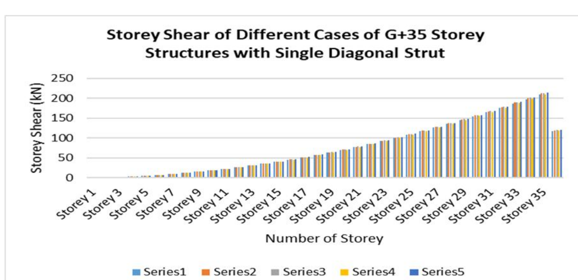

Fig.25 SS of G+35 of diff. cases with SDS

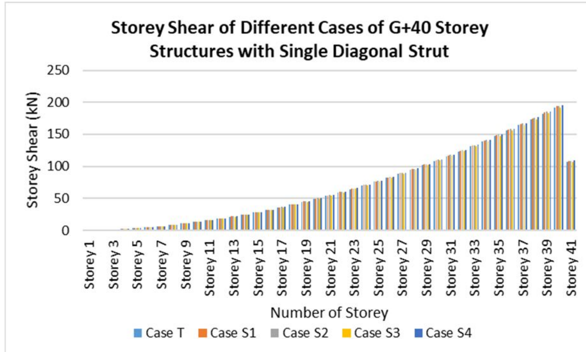

Fig.26 SS of G+40 of diff. cases with SDS

The comparison of analysed results of different cases with single – diagonal strut of G+25, G+30, G+35 and G+40 storey structure has shown in Fig. 23 to Fig. 26 respectively. From the study of figures, it has observed that case S4 of G+25, G+30, G+35 and G+40 that the storey shear has increased by 1.89%, 1.77%, 1.90% and 1.90% respectively.

2) With Cross Diagonal Strut

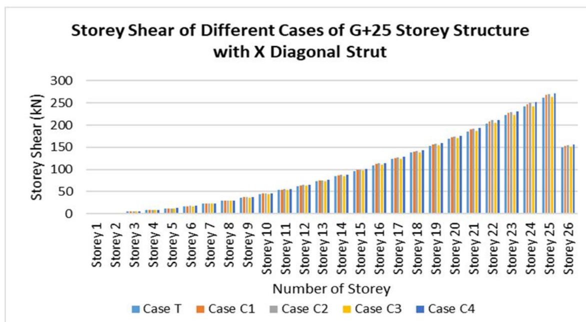

Fig.27 SS of G+25 of diff. cases with CDS

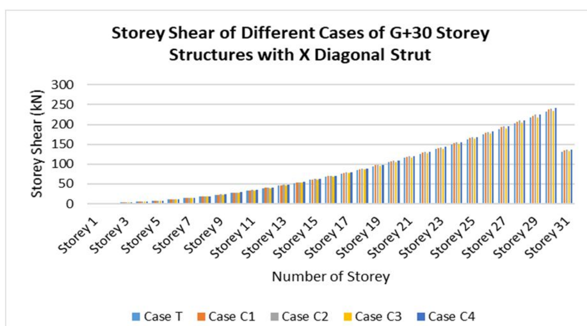

Fig.28 SS of G+30 of diff. cases with CDS

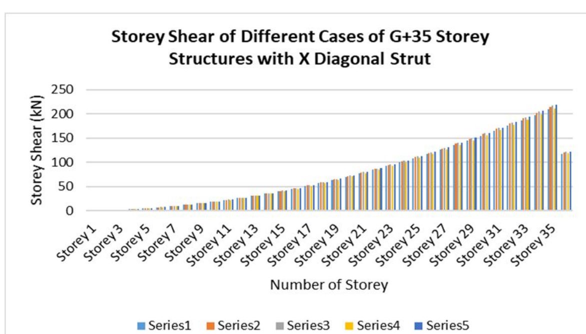

Fig.29 SS of G+35 of diff. cases with CDS

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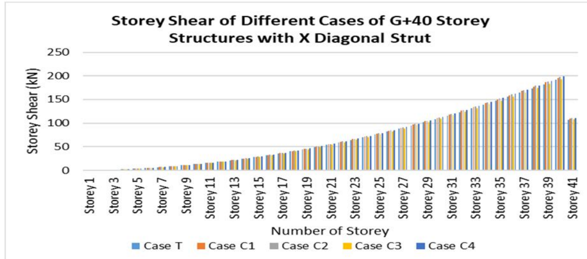

Fig.30 SS of G+40 of diff. cases with CDS

The comparison of analysed results of different cases with cross – diagonal strut of G+25, G+30, G+35 and G+40 storey structure has shown in Fig. 27 to Fig. 30 respectively. From the study of figures, it has observed that case S4 of G+25, G+30, G+35 and G+40 that the storey shear has increased by 3.78%, 3.67%, 3.80% and 3.81% respectively.

D. Comparison Of Results Of Base Shear Of Different Storey Structure For Different Cases

The comparison of analysed results of base shear is done as per the providing the diagonal strut. The comparison of analysed results is shown graphically from Fig. 31 to Fig. 34 and Fig. 35 to Fig. 38 for single diagonal strut and cross – diagonal strut respectively.

1) With Single Diagonal Strut

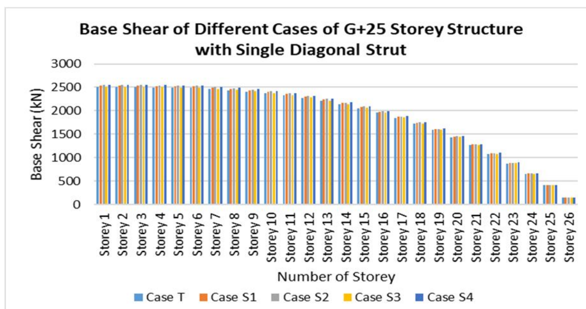

Fig.31 BS of G+25 of diff. cases with SDS

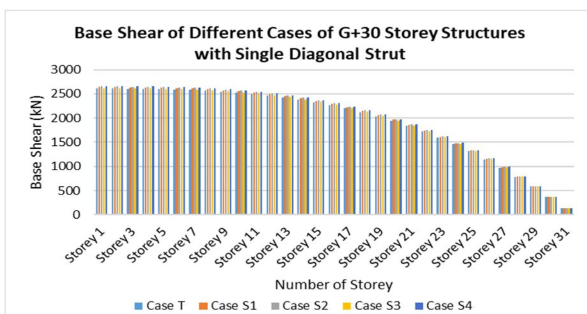

Fig.32 BS of G+30 of diff. cases with SDS

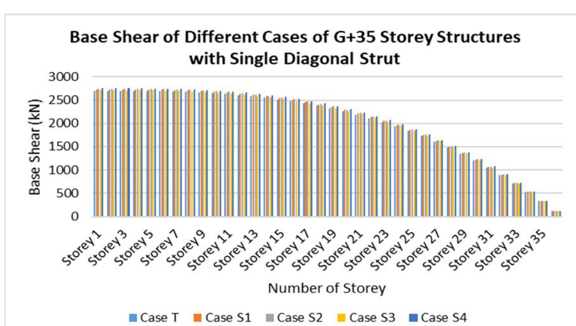

Fig.33 BS of G+35 of diff. cases with SDS

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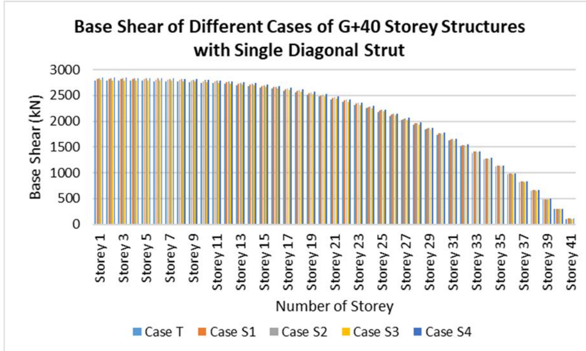

Fig.34 BS of G+40 of diff. cases with SDS

The comparison of analysed results of different cases with single – diagonal strut of G+25, G+30, G+35 and G+40 storey structure has shown in Fig. 31 to Fig. 34 respectively. From the study of figures, it has observed that case S4 of G+25, G+30, G+35 and G+40 that the base shear has increased by 2.01%, 1.88%, 2.02% and 2.02% respectively.

2) With Cross Diagonal Strut

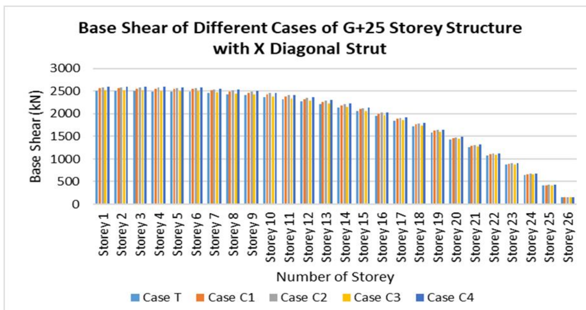

Fig.35 BS of G+25 of diff. cases with CDS

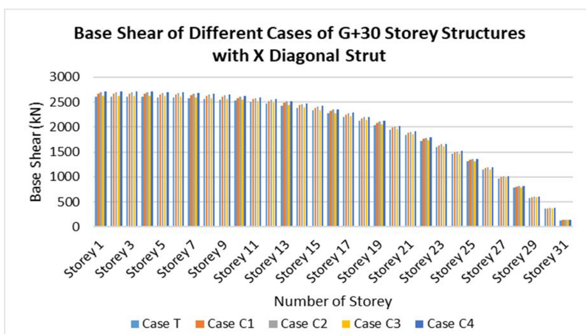

Fig.36 BS of G+30 of diff. cases with CDS

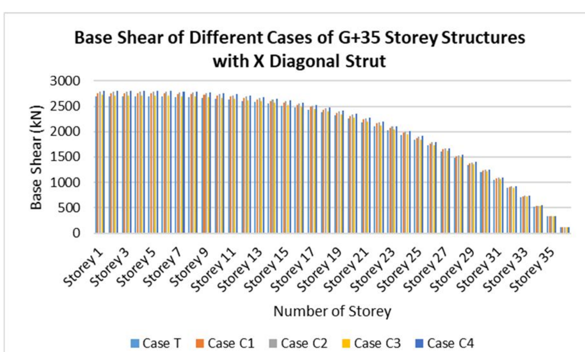

Fig.37 BS of G+35 of diff. cases with CDS

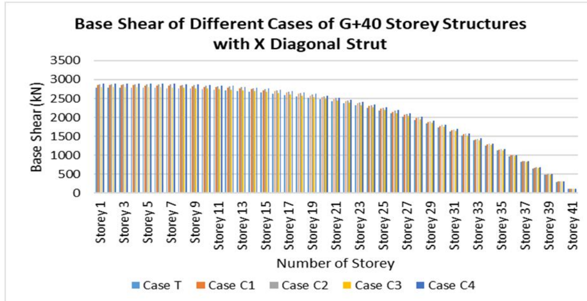

Fig.38 – BS of G+40 of diff. cases with CDS

The comparison of analysed results of different cases with cross – diagonal strut of G+25, G+30, G+35 and G+40 storey structure has shown in Fig. 35 to Fig. 38 respectively. From the study of figures, it has observed that case S4 of G+25, G+30, G+35 and G+40 that the base shear has increased by 4.02%, 3.91%, 4.02% and 4.05% respectively.

E. Comparison Of Results Of Storey Stiffness Of Different Storey Structure For Different Cases

The comparison of analysed results of base shear is done as per the providing the diagonal strut. The comparison of analysed results is shown graphically from Fig. 39 to Fig. 42 and Fig. 42 to Fig. 46 for single diagonal strut and cross – diagonal strut respectively.

1) With Single Diagonal Strut

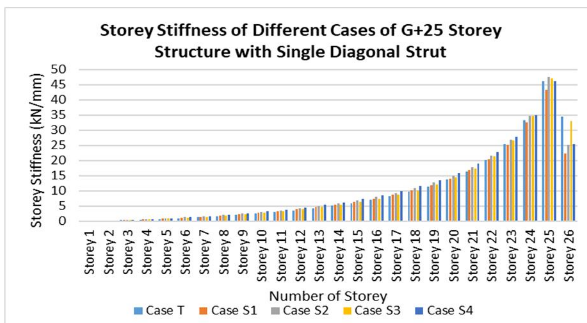

Fig.39 SS of G+25 of diff. cases with CDS

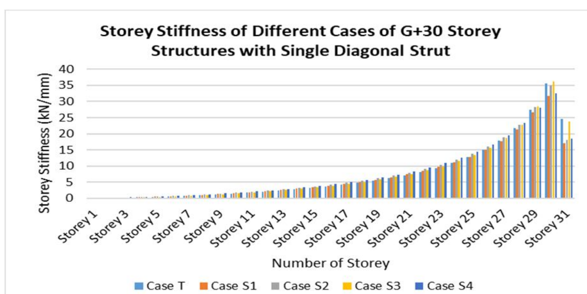

Fig.40 SS of G+30 of diff. cases with CDS

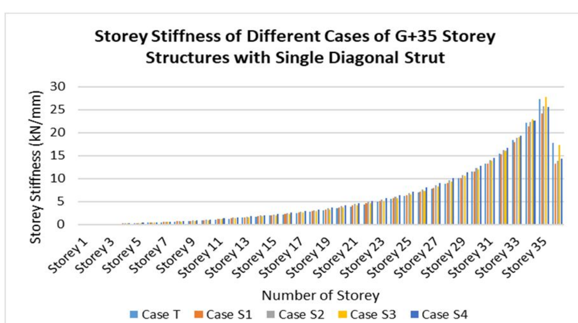

Fig.41 SS of G+35 of diff. cases with CDS

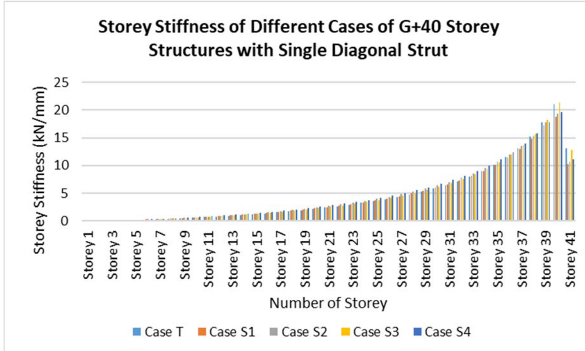

Fig.42 SS of G+40 of diff. cases with CDS

The comparison of analysed results of different cases with single – diagonal strut of G+25, G+30, G+35 and G+40 storey structure has shown in Fig. 39 to Fig. 42 respectively. From the study of figures, it has observed that case S4 of G+25, G+30, G+35 and G+40 that the storey stiffness has decreased by 26.81%, 24.28%, 19.51% and 15.52% respectively.

2) With Cross Diagonal Strut

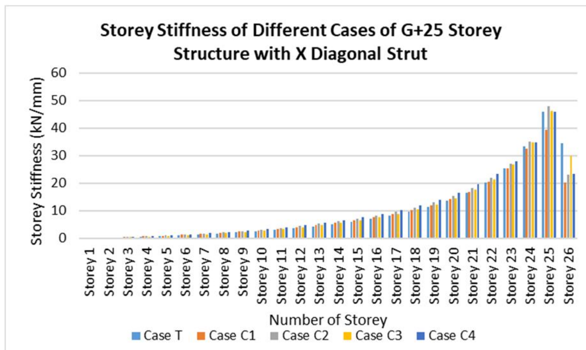

Fig.43 SS of G+25 of diff. cases with CDS

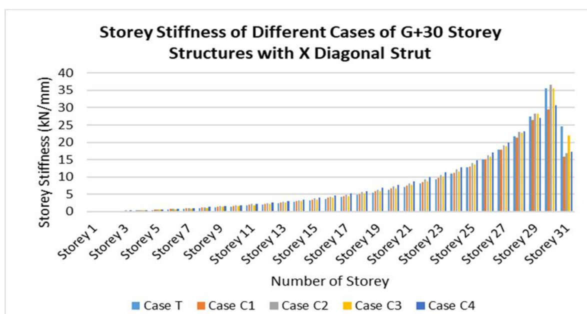

Fig.44 SS of G+30 of diff. cases with CDS

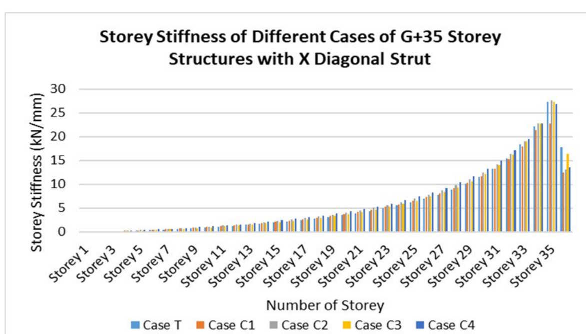

Fig.45 SS of G+35 of diff. cases with CDS

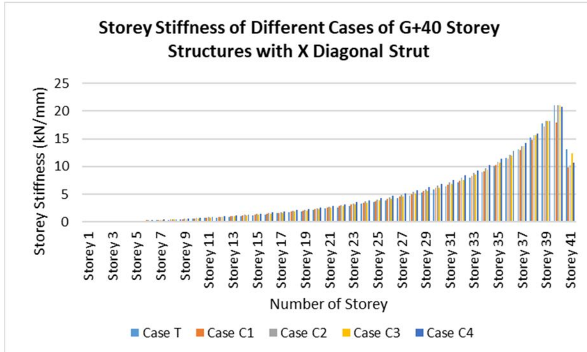

Fig.46 SS of G+30 of diff. cases with CDS

The comparison of analysed results of different cases with cross – diagonal strut of G+25, G+30, G+35 and G+40 storey structure has shown in Fig. 43 to Fig. 46 respectively. From the study of figures, it has observed that case S4 of G+25, G+30, G+35 and G+40 that the storey stiffness has decreased by 32.50%, 29.69%, 23.31% and 18.65% respectively.

V. CONCLUSIONS

From the analysed results of shear framed multi – storey structure using diagonal strut at different locations, the following conclusion are mapped on structural property –

A. From the statement of SDS and CDS structures, it is observed that when single and cross – diagonal strut is provided at corners, middle bay and centre of the structure as core, the lateral displacement is decreased with increase in height of structure. When case S4 of G+25 storey with SDS studied, it found that the lateral displacement decreased by 18.51% but when case S4 of G+40 storey with SDS studied, it found that the lateral displacement decreased up to 14.27%. Similarly, when case C4 of G+25 storey with CDS studied, it found that the lateral displacement decreased by 21.71% but when case C4 of G+40 storey with CDS studied, it found that the lateral displacement decreased up to 16.32%.

B. From the statement of storey drift of SDS and CDS structures, it is observed that when single and cross – diagonal strut is provided at corners, middle bay and centre of the structure as core, the storey drift is decreased with increase in height of structure. When case S4 of G+25 storey with SDS studied, it found that the storey drift decreased by 39.21% but when case S4 of G+40 storey with SDS studied, it found that the storey drift decreased up to 20.62%. Similarly, when case C4 of G+25 storey with CDS studied, it found that the storey drift decreased by 53.75% but when case C4 of G+40 storey with CDS studied, it found that the storey drift decreased up to 27.61%.

C. From the narration of storey shear of SDS and CDS structures, it is observed that when single and cross – diagonal strut is provided at corners, middle bay and centre of the structure as core, the storey shear is increased with increase in height of structure. When case S4 of G+25 storey with SDS studied, it found that the storey shear increased by 1.89% but when case S4 of G+40 storey with SDS studied, it found that the storey shear increased up to 1.90%. Similarly, when case C4 of G+25 storey with CDS studied, it found that the storey shear increased by 3.78% but when case C4 of G+40 storey with CDS studied, it found that the storey shear increased up to 3.81%.

D. From the description of base shear of SDS and CDS structures, it is observed that when single and cross – diagonal strut is provided at corners, middle bay and centre of the structure as core, the base shear is increased with increase in height of structure. When case S4 of G+25 storey with SDS studied, it found that the base shear increased by 2.01% but when case S4 of G+40 storey with SDS studied, it found that the base shear increased up to 2.02%. Similarly, when case C4 of G+25 storey with CDS studied, it found that the base shear increased by 4.02% but when case C4 of G+40 storey with CDS studied, it found that the base shear increased up to 4.05%.

E. From the discussion of storey stiffness of SDS and CDS structures, it is observed that when single and cross – diagonal strut is provided at corners, middle bay and centre of the structure as core, the storey stiffness is decreased with increase in height of structure. When case S4 of G+25 storey with SDS studied, it found that the storey stiffness decreased by 26.81% but when case S4 of G+40 storey with SDS studied, it found that the storey stiffness decreased up to 15.52%. Similarly, when case C4 of G+25 storey with CDS studied, it found that the storey stiffness decreased by 32.50% but when case C4 of G+40 storey with CDS studied, it found that the storey stiffness decreased up to 18.65%.

Hence, From the above conclusions it has been summarized that lateral displacement, storey drift, storey shear, base shear and storey stiffness are affected by single – diagonal strut and cross – diagonal strut.

Shear frame structure (case T) is more vulnerable in earthquake. Equivalent diagonal strut model for infill wall is useful to analyse the behaviour of infill wall. From the overall analysis of results, it may be concluded that considering all parameters the performance of structures with strut at outer corners with middle bay and as core (case S4 and case C4) is best. Structures with strut at outer corners with middle bay (case S2 and case C2) and structure with strut at outer corners are net in performance as their results lie near to structures with strut at outer corners with middle bay and as core (case S4 and case C4). Also, it is concluded that the performance of CDS is better than SDS in earthquake.

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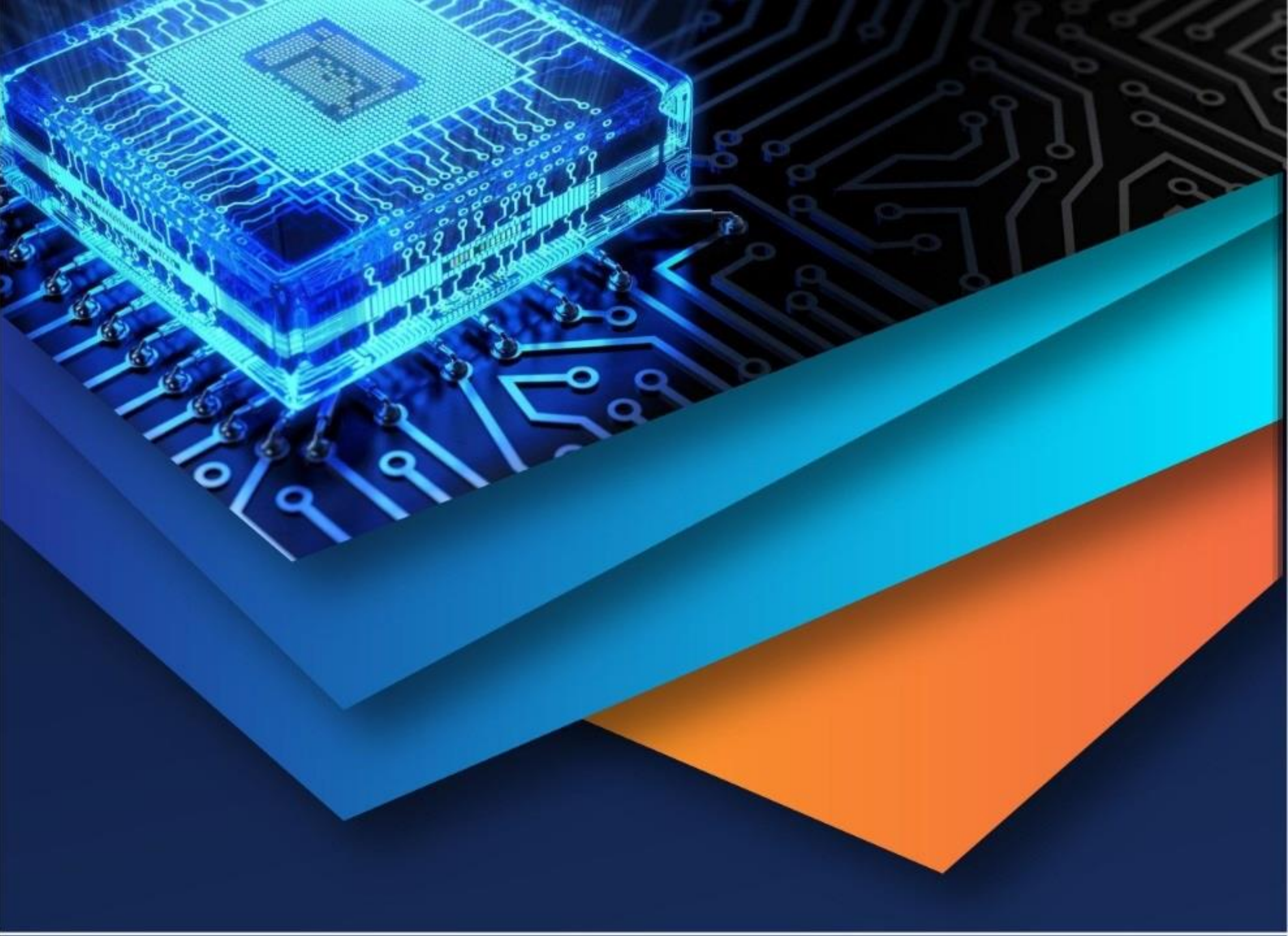

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