Comparative Seismic Analysis of Multi Storey RC Building by Considering the Effect of Dual System

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Abstract— Due to the current progress in world population, people in this world tend to occupy available locations present in any zone which also include zones falling in the high seismic zone categories. The structures to be built in these seismic zones are more susceptible to earthquakes for obvious reasons, and the structures constructed in such zones must be analysed and designed for the unpredictable earthquakes with unpredictable magnitudes by various lateral load resisting systems such as shear walls, bracings, tubular systems, coupled shear walls and even a combination of two load resisting systems called as dual systems. Present study includes linear-static and non-linear static analysis with different shear wall arrangements on dual systems such as flat slabs and shear walls & moment resisting frames and shear walls for different irregular plans using ETABS software. Parameters such as point displacements, base shears, pushover curves are studied.

Keywords: Dual Systems, Flat Slabs, Pushover Analysis, Shear Walls

I. Introduction

At present there has been a gigantic increment in the measure of high stories in current regions and their extraordinary fear is on the presence of the building which should be high slender. Thus it's critical for these buildings to oppose horizontal forces laterally with vertical forces. With this decisions the structure would be dealt with presentation wise, meanwhile the buildings being high and slender are exposed to seismic & wind loads. Dual system has been perceived to fight lateral loads viably, meanwhile it is a combination of two load resisting systems. Flat slab with shear wall and Moment Resisting Frame (MRF) with shear wall can be used as a dual system.

Buildings are usually designed for a minor seismic movement & experience a severe non-linear movement in earthquake defiant design. The performance and ductility characteristics of a structure are obligatory in order to study the structure under breakdown. True dynamic analysis is most of the times not viable and hence in the recent years an analysis called pushover analysis is being used which assesses various parameters such as, base shear, displacement, loads drifts, etc.

The dual system is used to resist lateral loads by merging the two lateral load resisting systems. In this systems the profile of the distortion will be different from those in wall and frame systems, where causing interlaced force take place and modification of the figure of shear and moment diagrams. The advantage of this combination is that the frames support the wall at the topmost & control their displacement and the wall supports the frame at the bottommost and declines their displacement. It delivers an enhanced immunity to the structure subsisting in an earthquake prone zone. A variety of Dual systems can be used such as special moment resisting frame (SMRF) with Shear walls, SMRF with Bracing, SMRF with Infill wall, Flat Slabs with Shear wall, Bracing and Infill wall each etc.

II. Methodology

A G+14 storey building measuring 30m x 25m in plan having E- Shape and diaphragm discontinuity is modelled. There are 10 models analysed in the present study by considering SMRF with flat slab and shear wall as dual system. Shear walls are used for E-shaped and diaphragm discontinuity models at different locations. For the present study, nonlinear static analysis and linear static analysis is considered.

A. Description of Building Structure

The details of building is given in Table 1

STRUCTURE	DESCRIPTION
Plan Dimension	30mx25m
No of Stories	15
Height of one storey	3 m
Height of Base Storey	3.5 m
Soil Type	Medium Soil
Seismic Zone	V
Importance Factor	1
Grade of Concrete f_{ck}	M30
Grade of Steel f_y	Fe 415
Size of the Beam	300mmX450mm
Size of the Column	500mmX500mm
Slab Thickness	150 mm
Live Load	3 kN/m^2
Live Load on Roof	2.5 kN/m^2
Floor Finish	1 kN/m^2
Column Drop	300mm
Shear Wall Thickness	200mm

Table 1:

III. Modeling and Analysis

Analytical study of equivalent static analysis and push over analysis to obtain various results like base shear, storey shear, storey drift & point displacement are considered. The results obtained after analysing by both linear and non-linear static analysis are compared for model 1 to model 10.

E-Shaped Bare Frame model. (M1)

E- Shaped model with SMRF and shear wall at re-entrant corners. (M2)

E- Shaped model with SMRF and shear wall at Alternate Periphery. (M3)

E- Shaped model with Flat Slab and shear wall at re-entrant corners. (M4)

E- Shaped model with Flat Slab and shear wall at Alternate Periphery. (M5)
Diaphragm discontinuity bare frame model (M6)
Diaphragm discontinuity model with SMRF and shear wall at corners (M7)
Diaphragm discontinuity model with SMRF and shear wall at alternate Periphery (M8)
Diaphragm discontinuity model with Flat Slab and shear wall at corners (M9)
Diaphragm discontinuity model with Flat Slab and shear wall at alternate Periphery (M10)

IV. RESULTS

A. *Base Shear*

M1 (kN)	M2 (kN)	M3 (kN)	M4 (kN)	M5 (kN)
4805.26	5194.11	5323.72	4880.52	5038.8

Table 2: Base Shears for "E-Shaped" model

M6 (kN)	M7 (kN)	M8 (kN)	M9 (kN)	M10 (kN)
5256.46	5688.92	5904.54	5499.18	5657.47

Table 3: Base Shears for "Diaphragm Discontinuity" model

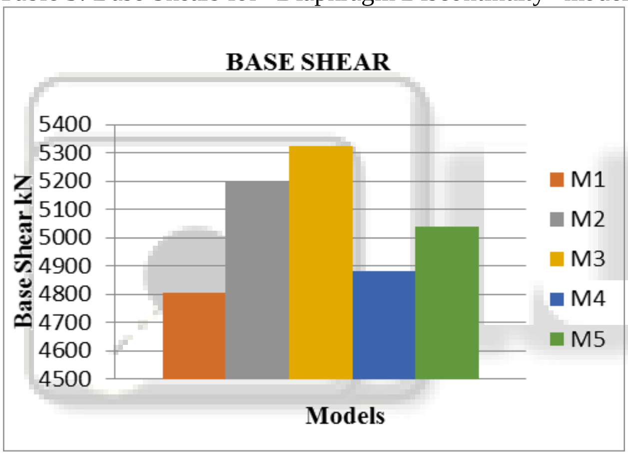

Fig. 11: Base Shear for Model 1 to Model 5

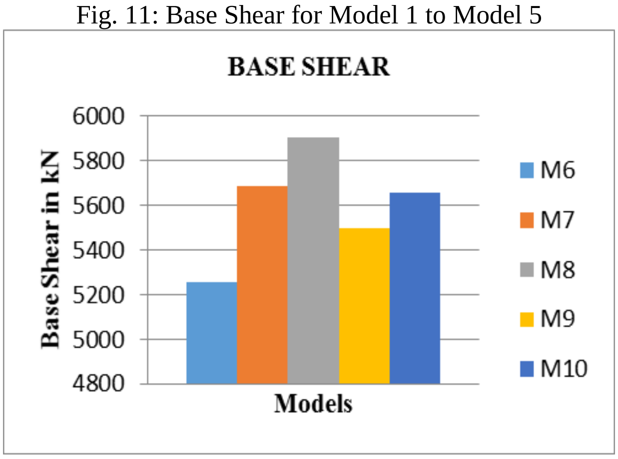

Fig. 12: Base Shear for Model 1 to Model 5

B. *Storey Shear*

STOREY NO	M1 (kN)	M2 (kN)	M3 (kN)	M4 (kN)	M5 (kN)
15	796.87	829.8	840.71	776.16	792.22
14	1562.73	1663.65	1697.24	1560.34	1603.57
13	2224.28	2383.94	2437.11	2237.73	2304.43
12	2789.16	2998.97	3068.87	2816.12	2902.87
11	3265	3517.05	3601.05	3303.35	3406.98
10	3659.43	3946.5	4042.18	3707.22	3824.84
9	3980.08	4295.63	4400.79	4035.55	4164.54
8	4234.59	4572.73	4685.44	4296.15	4434.17
7	4430.58	4786.13	4904.64	4496.83	4641.81
6	4575.7	4944.13	5066.93	4645.42	4795.55
5	4677.57	5055.04	5180.86	4749.73	4903.47
4	4743.82	5127.17	5254.95	4817.56	4973.65
3	4782.08	5168.83	5297.75	4856.74	5014.19
2	4800	5188.34	5317.79	4875.09	5033.17
1	4805.26	5194.11	5323.72	4880.52	5038.8

Table 4: Storey Shears for "E" shaped model

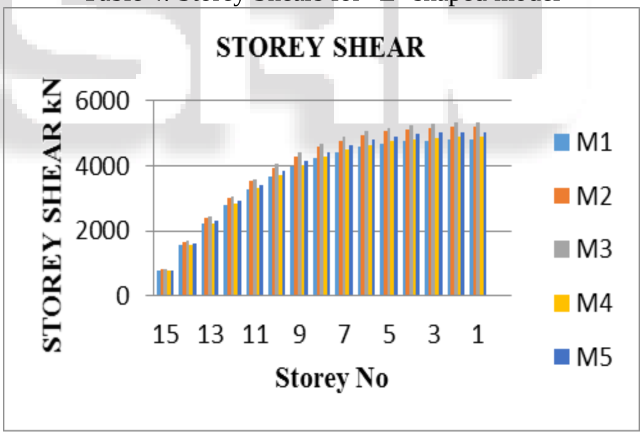

Fig. 13: Variation of Storey Shear for model 1-5

The above Table 4 shows the storey shear for E shaped model 1 to model 5. Storey shear goes on decreases as the storey high increases. It is seen that storey shear for model 4 is less on top storey compared to other models. The Fig 13 shows the graphical representation of storey shear for model 1 to model 5.

STOREY NO	M6 (kN)	M7 (kN)	M8 (kN)	M9 (kN)	M10 (kN)
15	876.61	905.05	931.43	874.05	890.11
14	1713.44	1819.06	1881.6	1757.74	1800.97
13	2436.3	2608.59	2702.36	2521.07	2587.77
12	3053.53	3282.75	3403.19	3172.85	3259.6

11	3573.46	3850.64	3993.54	3721.9	3825.53
10	4004.45	4321.38	4482.9	4177.01	4294.63
9	4354.82	4704.06	4880.72	4547	4676
8	4632.91	5007.81	5196.48	4840.67	4978.69
7	4847.07	5241.72	5439.64	5066.82	5211.79
6	5005.63	5414.91	5619.68	5234.26	5384.38
5	5116.94	5536.48	5746.06	5351.8	5505.54
4	5189.33	5615.55	5828.26	5428.24	5584.33
3	5231.14	5661.22	5875.73	5472.39	5629.84
2	5250.72	5682.6	5897.96	5493.06	5651.15
1	5256.46	5688.92	5904.54	5499.18	5657.47

Table 5: Storey Shears for "Diaphragm Discontinuity" model

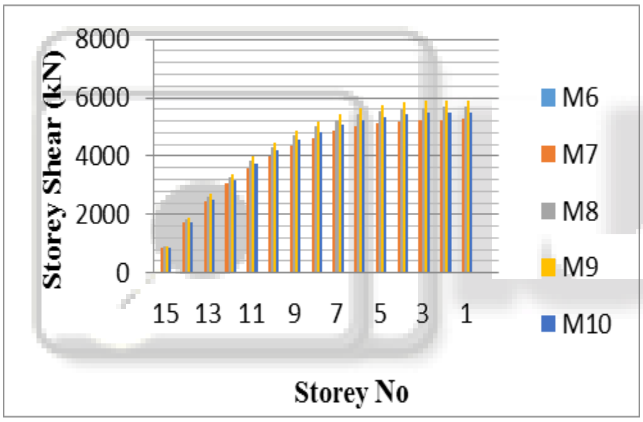

Fig. 14: Variation of Story Shear for model 6 – 10

The above Table 5 shows the point displacement for diaphragm discontinuity model 6 to model 10. Storey shear goes on decreases as the storey height increases. It is seen that storey shear for model 9 is less on top storey compared to other models. The Fig 14 shows variation of storey shear for model 6 to model 10.

C. Storey Drifts

STOREY NO	M1 (m)	M2 (m)	M3 (m)	M4 (m)	M5 (m)
15	0.00172	0.00130	0.00192	0.00106	0.00194
14	0.00225	0.00137	0.00194	0.00112	0.00196
13	0.00278	0.00142	0.00196	0.00117	0.00197
12	0.00326	0.00150	0.00195	0.00125	0.00195
11	0.00367	0.00150	0.00195	0.00125	0.00195
10	0.00399	0.00152	0.00192	0.00127	0.00192
9	0.00424	0.00152	0.00186	0.00128	0.00186
8	0.00442	0.00149	0.00178	0.00127	0.00178
7	0.00454	0.00144	0.00168	0.00123	0.00166
6	0.00461	0.00136	0.00154	0.00117	0.00152
5	0.00461	0.00125	0.00136	0.00108	0.00135
4	0.00455	0.00110	0.00115	0.00095	0.00114
3	0.00438	0.00091	0.00091	0.00079	0.00089
2	0.00393	0.00067	0.00062	0.00059	0.00060
1	0.00238	0.00032	0.00026	0.0003	0.00025

Table 6: Storey Drift for "E" shaped model

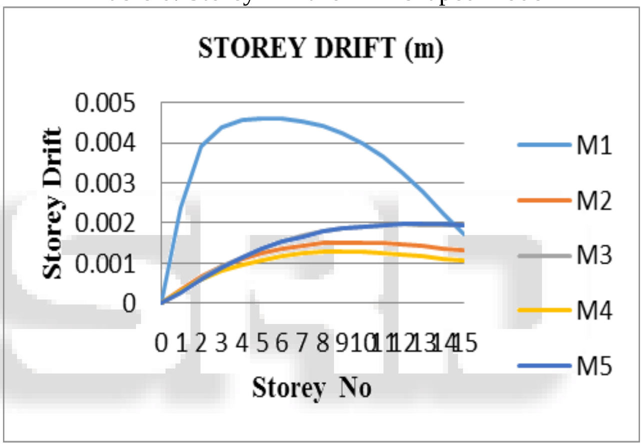

Fig. 15: Variation of Storey Drift for Model 1 to Model 5

The above Table 6 shows the storey drift for E shaped model 1 to model 5. Storey drift goes on increases as the storey height increases. It is seen that storey drift for model 5 is more on top storey compared to other models. The Fig-15 indicate the graphical representation of story drift for model 1 to model 5.

STOREY NO	M6 (m)	M7 (m)	M8 (m)	M9 (m)	M10 (m)
15	0.00108	0.00181	0.00016	0.00147	0.00015
14	0.00161	0.00185	0.00016	0.00150	0.00016
13	0.00213	0.00187	0.00017	0.00153	0.00016
12	0.00260	0.00188	0.00017	0.00155	0.00017
11	0.00300	0.00188	0.00018	0.00156	0.00017
10	0.00333	0.00186	0.00018	0.00155	0.00017
9	0.00359	0.00182	0.00017	0.00152	0.00017

8	0.00379	0.00175	0.00017	0.00147	0.00016
7	0.00394	0.00165	0.00016	0.00140	0.00015
6	0.00405	0.00152	0.00015	0.00130	0.00014
5	0.00411	0.00136	0.00014	0.00117	0.00013
4	0.00412	0.00116	0.00012	0.00100	0.00012
3	0.00406	0.00093	0.00010	0.00081	0.00010
2	0.00379	0.00065	0.00008	0.00058	0.00008
1	0.00238	0.00030	0.00005	0.00027	0.00005

Table 7: Story Drifts for "Diaphragm Discontinuity" model

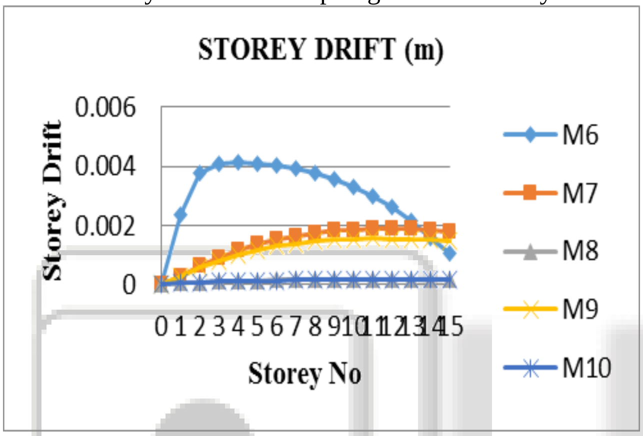

Fig. 16: Variation of Storey Drift for Model 6 to Model 10

The above Table 7 shows the storey drift for diaphragm discontinuity model 6 to model 10. Storey drift energies on decreases as the storey height increases. It is seen that storey drift for model 10 is less on top storey compared to other models. The Fig 16 shows the difference of storey drift for model 6 to model 10.

D. Point Displacement

STOREY NO	M1 (m)	M2 (m)	M3 (m)	M4 (m)	M5 (m)
15	0.1567	0.0487	0.0379	0.0426	0.0352
14	0.1505	0.0452	0.0348	0.0397	0.0322
13	0.1448	0.0417	0.0315	0.0366	0.0292
12	0.1374	0.0379	0.0283	0.0333	0.0262
11	0.1287	0.0341	0.02511	0.03	0.0232
10	0.1187	0.0301	0.0219	0.0266	0.0202
9	0.1078	0.0262	0.0187	0.02319	0.0173
8	0.0961	0.0223	0.01564	0.0197	0.0144
7	0.0838	0.0184	0.0126	0.0163	0.0116
6	0.0712	0.0147	0.0099	0.0131	0.0091
5	0.0582	0.0112	0.0073	0.01004	0.0067
4	0.045	0.008	0.0051	0.0072	0.0046
3	0.0323	0.0052	0.0031	0.00475	0.0028
2	0.0196	0.0029	0.00162	0.00265	0.0014
1	0.0081	0.0011	0.00055	0.00100	0.00051

Table 8: Point Displacement for "E" shaped model

The above Table 8 shows the point displacement for E shaped model 1 to model 5. Point displacement goes on increases as the storey height increases. It is seen that point displacement for model 1 is more on top storey compared to other models. The Fig 17 shows the variation of for model 1 to model 5.

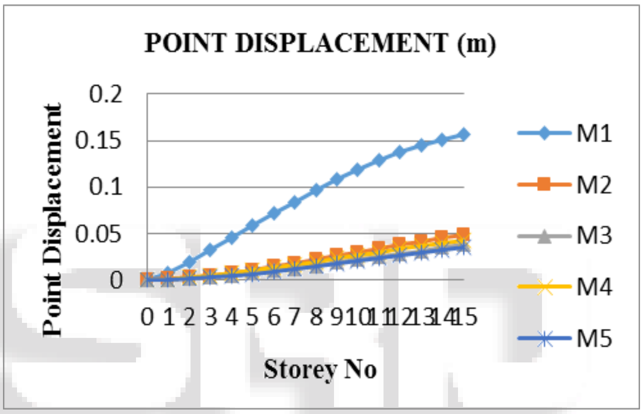

Fig. 17: Point Displacement for Model 1 to Model 5

STOREY NO	M6 (m)	M7 (m)	M8 (m)	M9 (m)	M10 (m)
15	0.1435	0.067	0.0066	0.0562	0.00638
14	0.1403	0.0616	0.0061	0.0518	0.00593
13	0.1355	0.056	0.00567	0.0472	0.00544
12	0.1291	0.0504	0.00515	0.0426	0.00494
11	0.1213	0.044	0.00462	0.038	0.00444
10	0.1123	0.0391	0.004	0.0333	0.00392
9	0.1023	0.0335	0.00355	0.02871	0.0034
8	0.0916	0.0281	0.00302	0.0241	0.0029
7	0.0802	0.0228	0.0025	0.01972	0.0024
6	0.06844	0.0179	0.00201	0.01552	0.0019
5	0.0563	0.0133	0.0016	0.0116	0.0015

4	0.044	0.0093	0.00114	0.0081	0.0011
3	0.0317	0.0058	0.0008	0.0051	0.0007
2	0.0195	0.003	0.0005	0.0027	0.0004
1	0.0082	0.001	0.0002	0.0009	0.0002

Table 9: Point Displacement for "Diaphragm Discontinuity" model

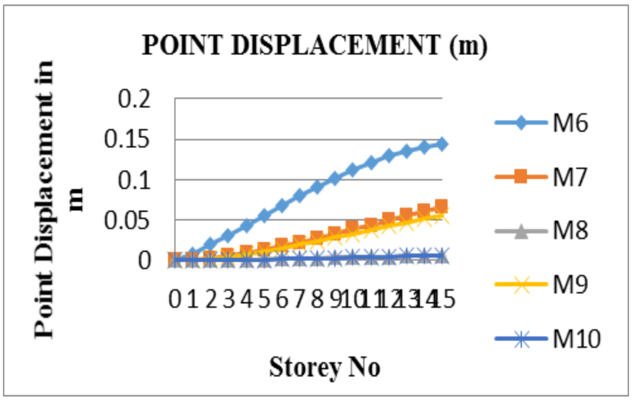

Fig. 18: Point Displacement for model 6 to model 10

The above Table 9 shows the point displacement for diaphragm discontinuity model 6 to model 10. Point displacement goes on increases as the storey height increases. It is understood that point displacement for model 6 is more on top storey compared to other models. The Fig 18 indicate the variation of storey drift for model 6 to model 10.

E. Pushover Curves

1) Pushover curves For E-Shaped (ES) & Diaphragm discontinuity (DD) Model

STEP	DISPLACEMENT(m)		BASEFORCE(kN)	
	ES	DD	ES	DD
0	0	0	0	0
1	0.0475	0.1251	1603.065	4591.635
2	0.0508	0.2442	1698.246	8481.374
3	0.0539	0.2758	1734.596	8997.638
4	0.0696	0.3189	1818.701	9337.473
5	0.2548	0.3698	2214.583	9542.388
6	0.4439	0.3698	2489.943	9319.982
7	0.5222	0.3755	2589.558	9382.83
8	0.4906	0.3755	1426.410	9322.377
9	-	0.3791	-	9380.440
10	-	0.3888	-	9468.168
11	-	0.4003	-	9506.372
12	-	0.3365	-	6911.181

Table 10: Pushover table for Bare Frame

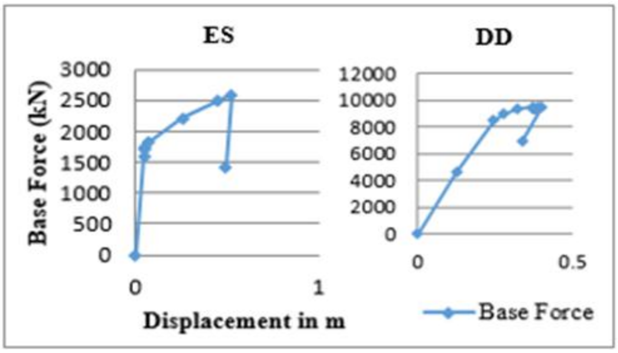

Fig. 19: Pushover curve for Bare Frame

STEP	DISPLACEMENT(m)		BASEFORCE(kN)	
	ES	DD	ES	DD
0	0	0	0	0
1	0.0068	0.0487	5220.751	4783.962
2	0.0451	0.2323	33153.54	21258.01
3	0.0451	0.4154	33133.69	33546.32
4	0.0511	0.4801	37178.76	37047.35
5	0.0511	0.2201	37029.01	11337.46
6	0.0577	-	41218.21	-
7	0.0577	-	40992.84	-
8	0.0583	-	41403.96	-
9	0.0583	-	41254.33	-
10	0.0593	-	41827.11	-
11	0.0593	-	41739.27	-
12	0.0611	-	42851.48	-
13	0.0611	-	42754.58	-
14	0.0627	-	43741.92	-
15	0.0627	-	43658.98	-
16	0.0651	-	45109.56	-

Table 11: Pushover table for SMRF with Shear Wall at re-entrant corner (ES) / corner (DD)

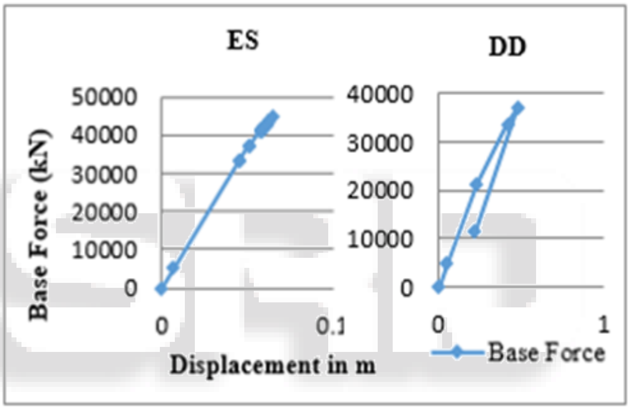

Fig. 21: Pushover curve for SMRF with Shear Wall at re-entrant corner

STEP	DISPLACEMENT(m)		BASEFORCE(kN)	
	ES	DD	ES	DD
0	0	0	0	0
1	0.0505	0.0181	6401.33	16257.56
2	0.2368	0.2015	28707.4	160802.5
3	0.4239	0.2899	47633.6	226149.2
4	0.4294	0.29	48154.4	225993.6
5	0.4294	0.3155	47702.3	246379.3
6	0.4747	0.2915	52178.60	224220.9
7	0.4747	-	51889.03	-
8	0.4912	-	53409.36	-
9	0.4912	-	53244.65	-
10	0.5253	-	56322.65	-
11	0.5099	-	54316.79	-

Table 12: Pushover table for SMRF with Shear Wall at Periphery

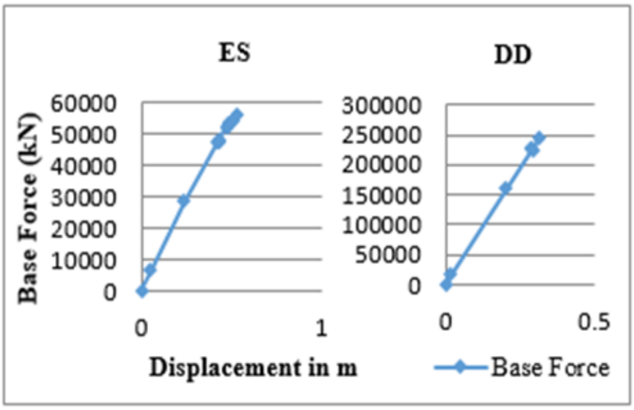

Fig. 23: Pushover curve for SMRF with Shear wall at Periphery (ES)

STEP	DISPLACEMENT(m)		BASEFORCE(kN)	
	ES	DD	ES	DD
0	0	0	0	0
1	0.0201	0.0499	2528.226	4247.221
2	0.2042	0.233	15904.85	15325.89
3	0.2754	0.4248	19972.79	23092.26
4	0.2754	0.5556	19900.62	28163.10
5	0.2786	0.5556	20102.83	28107.64
6	0.2786	0.6435	20073.12	31932.79
7	0.2789	0.6436	20089.54	31218.32
8	-	0.6837	-	32843.97
9	-	0.5826	-	24556.62

Table 13: Pushover table for Flat Slab with Shear Wall at re-entrant corner (ES) / corner (DD)

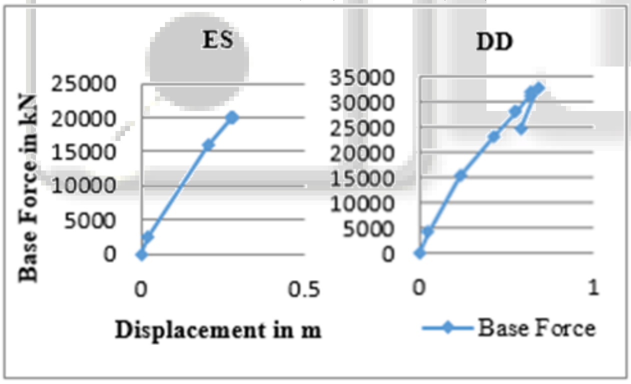

Fig. 25: Pushover curve for Flat Slab with Shear Wall at re-entrant corner/corner

STEP	DISPLACEMENT(m)		BASEFORCE(kN)	
	ES	DD	ES	DD
0	0	0	0	0
1	0.0071	0.0129	5338.762	11552.92
2	0.0401	0.1953	28348.52	147342.5
3	0.039	0.2713	27400.13	199444.1
4	-	0.2713	-	199304.3
5	-	0.2736	-	200972.6
6	-	0.2116	-	145484.1

Table 14: Pushover table for Flat Slab with Shear Wall at Periphery

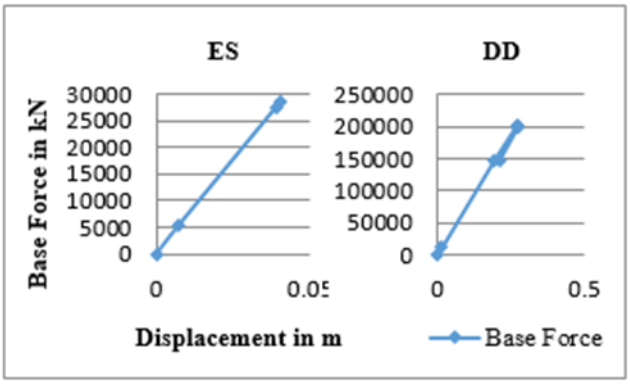

Fig. 27: Pushover curve for Flat Slab with Shear Wall at Periphery

V. CONCLUSIONS

1) In E shaped model the base shears and storey shears is found to be highest for SMRF with shear wall at periphery dual system when compared to all the other E shaped models.
2) Storey drifts obtained in E model for SMRF with shear wall at periphery dual system is far better compared to other models and 58.5% better than bare frame model.
3) 3 Point displacements obtained for E model illustrated better results for SMRF with shear walls at periphery dual system compared to other variants and about 62.29 % better than bare frame model.
4) From the graphs plotted it is clearly seen that the bare frame for E-Shaped & Diaphragm discontinuity model is the most vulnerable model in the seismic zone V owing to the absence of lateral load resisting system.
5) In Diaphragm discontinuity models, the base shears and storey shears indicated higher values for the model, flat slabs with shear walls at periphery, compared to other diaphragm discontinuity models.
6) Point displacements obtained for models with diaphragm discontinuity having, SMRF with shear wall at periphery and flat slab with shear wall at periphery show closely matching results with the previous model showing better result than the latter one and 90% better than bare frame model.
7) When both E-Shape and Diaphragm discontinuity models are compared, the graphs illustrated the Diaphragm discontinuity model with shear wall at periphery and flat slabs with shear walls at periphery showed a better performance for storey drift and point displacements compared to all other variants. Thus making it a better dual system than all the other systems considered in this study.

ACKNOWLEDGEMENT

I express my sincere gratitude to all my respected teachers for their invaluable guidance. I am grateful to my parents who have always been a constant source of inspiration and whose encouragement is beyond linguistic expression.

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