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Seismic Impact of Re-entrant Corner with Opening in Diaphragm on RC Building

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Abstract*: *The most important cause of damage of RC buildings during earthquake is the irregular building configuration. An RC building which are unsymmetrical and has lack of continuity in geometry, mass or load resisting elements is called as irregular buildings. This obstructs the flow of inertia forces and cause lots of damage to buildings. There are many studies carried out irregular buildings in seismic zones, but still more research is needed in this field. Therefore, this study is about the seismic response of reinforced concrete structures having combination of two plan irregularities, re-entrant corner and diaphragm discontinuity buildings. Study is performed combining this two plan irregularity criteria and analyzing the results in seismic zone 4 and 5. For this 1 is regular building, 3 re-entrant corner buildings with three variations in A/L ratio, three buildings with opening in diaphragm with three varying percentage of opening. 9 structures are made combining these buildings with the combination of two irregularities. Structures are analyzed in etas software. Parameters such as story displacement, story drift, base shear, overturning moments are determined and compared with regular buildings.

Keywords: Re-entrant corner, diaphragm discontinuity response spectrum, displacement, drift, base shear, overturning moment.

I. INTRODUCTION

When horizontal forces act at the base of the structure an inertia force are generated. These inertia forces are directly proportional to mass of the building. These inertia forces develop at the floor level as most of the building mass is present at the floor level. These inertia forces are transferred to the walls or the columns by slabs and then to the foundation which disperses them safely to ground. The flow of inertia force should be smooth and continuous through the building. As inertia forces accumulate downwards from the top of the building, the lower story experience higher forces than upper story. Therefore, the lower story should be designed stronger than the upper. The buildings having unsymmetrical geometrical configuration and discontinuity in diaphragm are more unstable in seismic affect than regular one.

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Many researchers carried out research work on irregular building design ins seismic zones. Komal R. Bele1, S. B. Borghate (2015) focused on buildings with large projections of Re-entrant corners results in torsion. He took four models one regular and other 3 with varying projections. The conclusion of this paper was base shear decreases from Model R to` L5 (decreases with increase in projection). He also concluded that as projection of increases there are more coupling of modes. Result obtained shows that forces in column (common in all building) shows that the variation of P much higher with increase in projection. Rakesh Sakale, R K Arora and Jitendra Chouhan (2014) studied seismic behaviour of horizontally irregular buildings with regular building. L-shape, T-shape, C-shape and regular shape buildings of equal height are taken and lateral displacement and story drift are derived after analysis. Results were compared and studied. Analysis is performed in staad pro. For seismic zone II, III, IV, and V. Results were such that from drift point of view for zone II TO IV all frames are within permissible limit and there is no need to provide shear wall. Only with the building with plan C exceeds the permissible limit and may require shear wall. For displacement point of view, all buildings are withing permissible limit only for zone II. In zone III and above regular plan building slightly exceeds the permissible limit but other requires shear wall to control the limit. Babita Elizabath baby and shreeja s (2015) studied slab discontinuity at different position that is at the centre, at corners, and at periphery. Pushover analysis are performed in etabs software. Results were that the axial forces, bending moment and story drift are more effectively resisted by the model having slab opening in periphery. So, the opening is more effective to be located at periphery. Shiva kumar hallale and H sharada bai (2016) took three building, one regular and another two with re-entrant corner building plan. Response spectrum method is used for analysing in etabs. Parameters such as eccentricity, maximum displacement and drift, base shear, max. story acceleration, time period, member force in beam and column. Results obtained were eccentricity, max displacements, max story, drift increases in both direction x and y with the increase in plan irregularities. Kazi Muhammed mustaqeem and md mansoor ahmad (2016) his research paper consists two types of configuration, one with opening in slabs and other re-entrant corner structure having varying percentage of irregularities. Analysis was performed for static analysis, dynamic analysis and push over analysis and parameters were displacement, drift, base shear and time period. The results were such that the magnitude of displacement is more in static method. Response spectrum showed more accurate results and can be better considered for seismic activity. Pushover analysis gives higher value as it is analyzed for extreme.

More percentage of re-entrant corner max drift. Base shear is max. for regular model less for re-entrant models. As base shear of the building increases, more seismic forces will be attracted by the member. Subodh. S.Patil, Shrinivas. R.Survanshi (2016) focused on seismic response of regular multi-storey building with asymmetrical plan is checked and compared with regular multi-storey building.

A building with g+20 and g+22 building having plan asymmetry is modelled and analysed in finite element analysis stadd pro v8i. shear wall is provided at re-entrant corner in the buildings. Results of this paper as increase in height of L-shape building directly increase in relative displacement & stress at re-entrant corners. Increase in height of T-shape building directly increase in relative displacement and stress will be developed at re-entrant corner. T-shape building with shear wall and without shear wall after analysis shows uniform stress developed at re-entrant corners. In T- shape building re-entrant corners did not fail because of stresses carried by the shear wall. But without shear wall it will fail. Reena sahu and Ravi dwivedi (2017) studied about diaphragm discontinuity taking 5 structures. One as regular and other 4 as the increasing percentage in slab opening 0%, 4%, 16%, 24%, 36%. Response spectrum analysis using staad pro. is done. Parameters like base shear, bending moment, story drift, shear force are obtained. Results shows that the increase in opening percentages, increases the story drift. 24% opening have less value of maximum shear force as compared to 16% opening. Akshay Nagpure, S. S. Sanghai (2018) studied RCC framed building structures which have been analyzed using ETABS software by linear time history analysis by changing flexibility of the floors and simultaneously when plan irregularities are provided. He took four plans- opening at the centre, opening at the corners, opening at the horizontal faces, opening at the vertical faces. Time history record of El Centro Earthquake has been provided to the software. Responses of all those structures has been plotted and discussed. An attempt is made in this paper to compare the responses of the structures when floor diaphragm flexibility is changed and simultaneously plan irregularities are provided. He concluded that floor Diaphragm Flexibility affects Base Shear of the Building, Column Forces, Beam Forces but doesn't show considerable difference in Time Period and Storey Drift. Sanjay Naik, Tushar S Shetty (2019) research paper involves the modelling and analysis of G+10 storied building of Regular shape plan, L- shape plan and C shape plan structure using ETABS 2016 software. The parameters such as displacement, drift, shear and overturning moment are compared and it was found that Rectangular shape is the best suited and L shape structure is the least desired shape for construction in seismic zone.

Research works has been done for various plan irregularities and vertical irregularities. Conclusion can be made after review of above literatures that unsymmetrical building shows more instability than regular one. The various parameters such as displacements, story drift, overturning moment shows large variations from regular building to plan irregular building and then to vertical irregular building. Shear wall provided is of great help in order to maintain the structural stability of the structure. Base isolation and seismic dampers can also be applied in or to reduce base shear, lateral displacement, story drift. Still very less work is carried out in the field of combinations of plan irregularity.

II. THEORY

As per IS 1893 Part 1 irregularities of two types:
paper in both email address.

1. Plan irregularities
2. Vertical irregularities

Re-entrant corners: inside corners of an asymmetrical building are subjected to stress concentration during earthquake motion. Thus, these corners are more prone to damage during earthquakes.

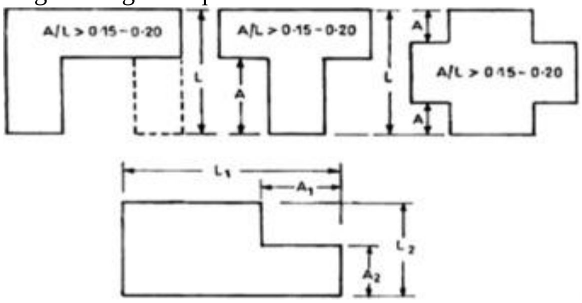

Fig. 1: Re-entrant corner

Diaphragm discontinuity: roof or floor acts as diaphragms (horizontal resisting elements). The diaphragm discontinuity is because of the cut-out or large openings. This causes reduction in the load carrying capacity of diaphragm and may cause damage during earthquake.

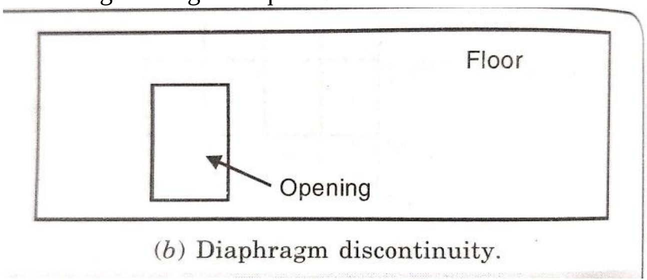

Fig. 2: Diaphragm discontinuity

III. OBJECTIVE OF STUDY

To study the retaliation of plan irregular structures as per IS 1893 part 1 in seismic zones IV and V and collate with reaction of regular building model.

IV. METHODOLOGY

(A). Review of the existing literatures by different researchers.

(B). G+14 story, 10 buildings are taken with 1 regular plan, 3 with varying re-entrant corner plan, 3 with varying opening in diaphragm, 3 with the combination of varying re-entrant corner and opening slab.

(C). Modelling and analysis are done as per IS 1893 part 1 by response spectrum method in etabs software for zone IV and V.

(D). Parameters such as base shear, max. story displacement, max. story drift, overturning moment are plotted in forms of tables and then graphs.

(E)results are collated with regular building models.

V. DETAILS OF THE BUILDING

For study purpose, the layout of the plan has 5 X 5 bays of equal length of 6m.

Building parameters are as follows –

- Type of building: SMRF
- Numbers of Storey: G+14
- Seismic zone: IV and V
- Floor height: 3m
- Grade of concrete: M35
- Grade of steel: Fe500
- Beam dimension: 400 x 700mm
- Column dimension: 450 x 800mm
- Slab depth: 150mm
- Dead load on floor: 0.52 KN/m2

Mortar screeding – 0.21 x 2 (IS 875 PART 1 table 2 page 31)

Clay floor tiles – 0.10 (IS 875 PART 1 table 2 page 30)

- Live load on floor: 2.5 KN/m2 (IS 875 PART 2 table 1)
- Masonry load: 4.59 KN/m (outer wall)

3.519 KN/m (inner wall)

[AAC (Autoclaved Aerated Concrete Block) is used.]

(unit weight of AAC blocks – 6 KN/m^3)

- Importance factor: 1
- Response reduction factor®: 5
- Site type: II
- % imposed load: 25%

VI. MODELS.

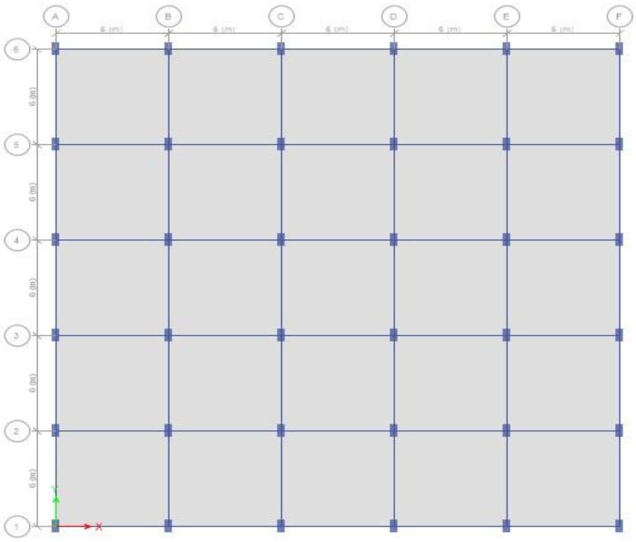

Fig. 3: MODEL R-REGULAR

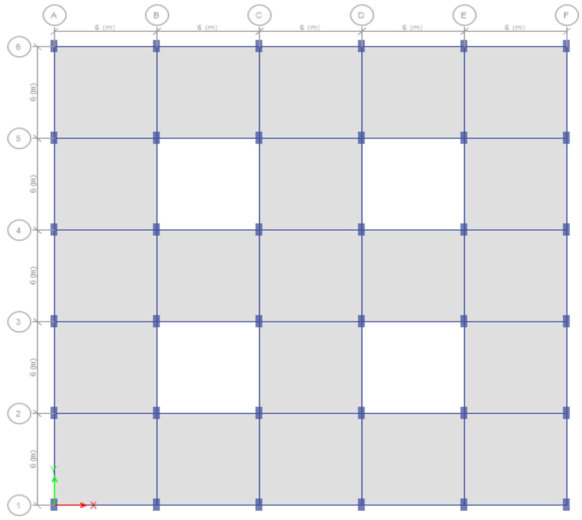

Fig. 4: MODEL D1 (16% OPENING)

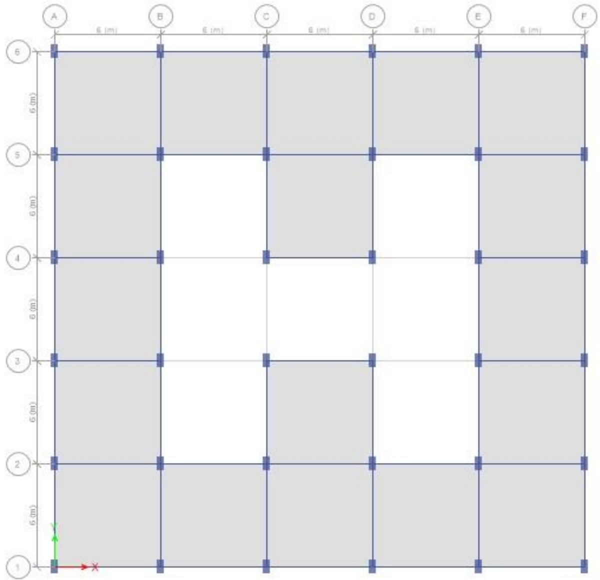

Fig. 5: MODEL D2 (28% OPENING)

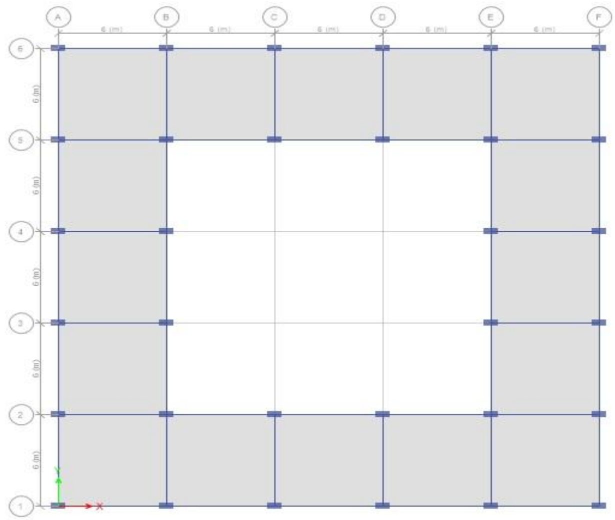

Fig. 6: MODEL D3 (36% OPENING)

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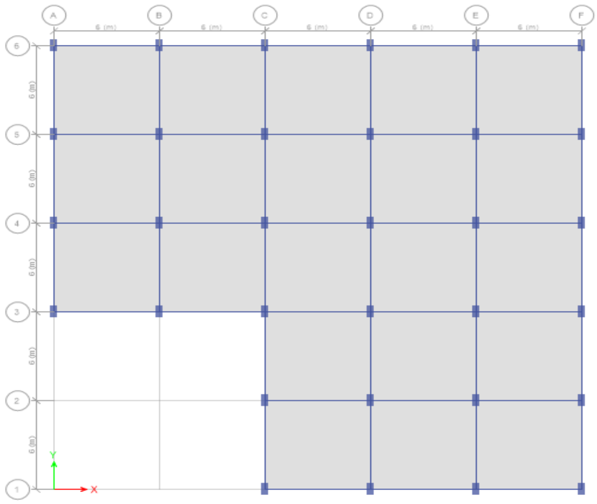

Fig. 7: MODEL R1 (RE ENTRANT CORNERS 40% IN X AND 40% IN Y)

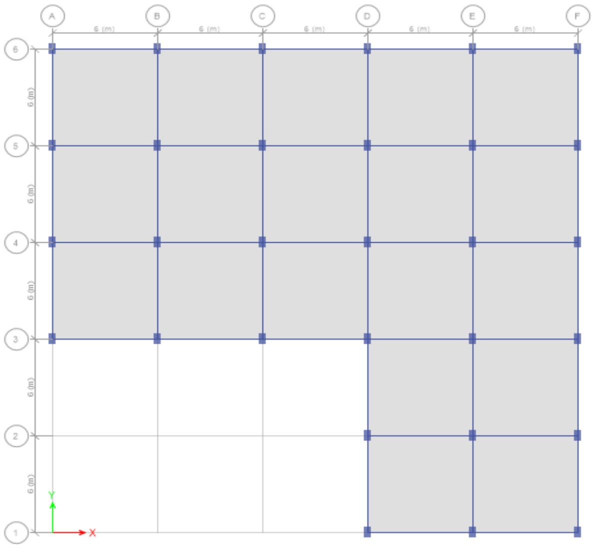

Fig. 8: MODEL R2 (RE ENTRANT CORNERS 60% IN X AND 40% IN Y)

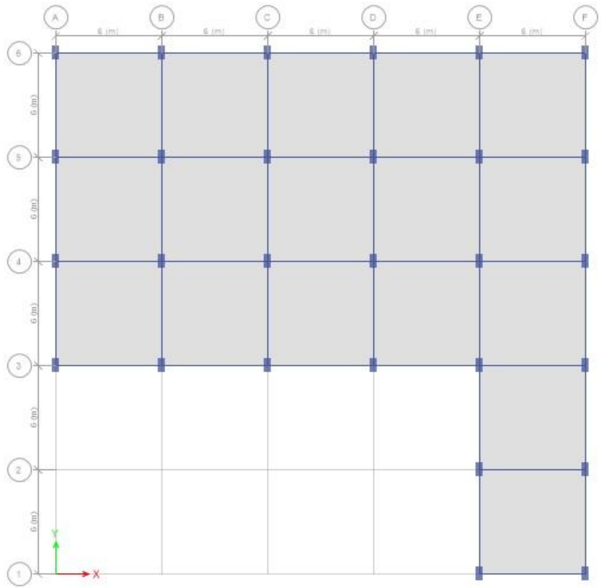

Fig. 9: MODEL R3 (RE ENTRANT CORNERS 80% IN X AND 40% IN Y)

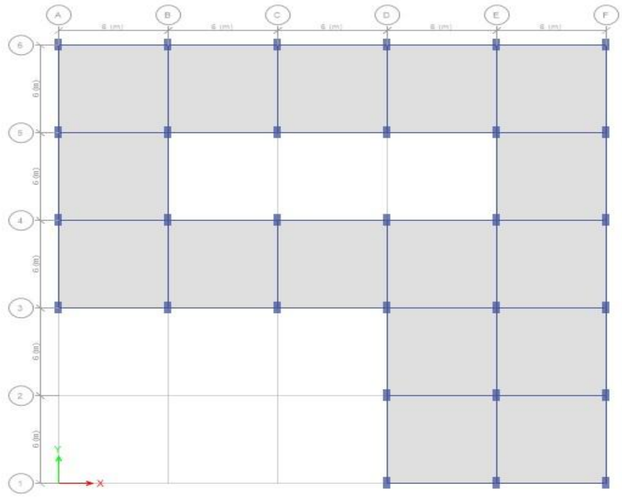

Fig. 10: MODEL DR1 (15% diaphragm opening and 60% re-entrant in x)

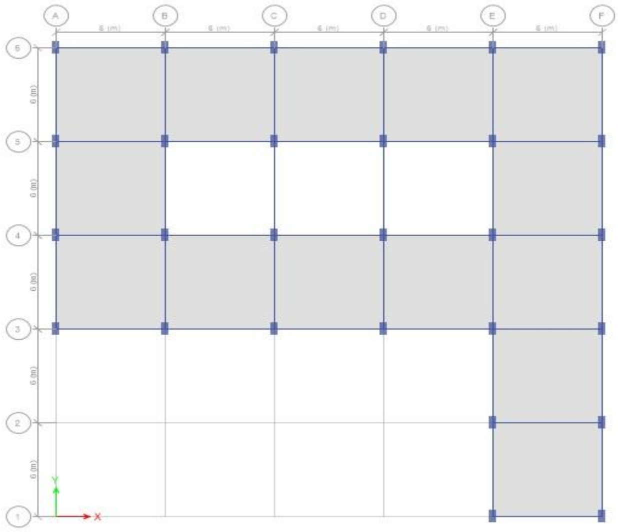

Fig. 11: MODEL DR2 (17% diaphragm opening and 80% re-entrant in x)

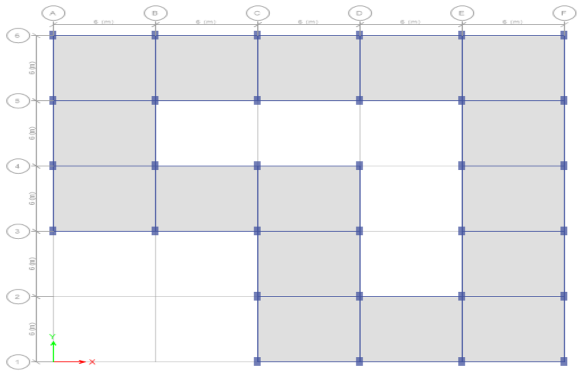

Fig. 12: MODEL DR3 (23% diaphragm opening and 40% re-entrant in x)

VII. RESULTS (Tables and graphs)

TABLE 1: Max. story displacement (mm) (ZONE IV)

STOREY	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
1	6.80	6.53	13.17	4.45	6.84	7.31	6.39	6.95	7.65	6.81
2	10.69	10.29	16.72	7.47	10.79	11.55	10.27	11.06	12.26	10.85
3	14.42	13.89	20.09	10.47	14.60	15.63	14.04	15.04	16.73	14.76
4	17.97	17.32	23.31	13.37	18.23	19.53	17.66	18.84	21.02	18.50
5	21.31	20.54	26.37	16.14	21.65	23.23	21.10	22.44	25.11	22.05
6	24.44	23.57	29.26	18.77	24.87	26.71	24.37	25.83	28.98	25.39
7	27.36	26.39	31.99	21.25	27.88	29.98	27.44	29.01	32.63	28.53
8	30.06	29.01	34.53	23.57	30.67	33.04	30.31	31.97	36.05	31.46
9	32.54	31.40	36.88	25.72	33.23	35.86	32.97	34.71	39.22	34.17
10	34.79	33.98	39.02	27.70	35.57	38.43	35.41	37.20	42.14	36.64
11	36.78	35.50	40.94	29.48	37.64	40.75	37.61	39.43	44.77	38.86
12	38.50	37.16	42.61	31.03	39.43	42.76	39.53	41.37	47.09	40.80
13	39.90	38.51	43.99	32.34	40.91	44.45	41.15	42.98	49.06	42.42
14	40.95	39.52	45.08	33.39	42.03	45.76	42.46	44.23	50.66	43.67

TABLE 2: Max. story drift (ZONE IV)

Sty.	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
1	0.00131	0.00126	0.00140	0.00090	0.00132	0.00141	0.00127	0.00136	0.00151	0.00133
2	0.00130	0.00125	0.00119	0.00101	0.00132	0.00141	0.00129	0.00137	0.00154	0.00135
3	0.00125	0.00121	0.00114	0.00100	0.00128	0.00137	0.00126	0.00134	0.00150	0.00131
4	0.00120	0.00116	0.00110	0.00098	0.00123	0.00132	0.00122	0.00129	0.00146	0.00127
5	0.00115	0.00111	0.00107	0.00095	0.00118	0.00128	0.00118	0.00124	0.00141	0.00122
6	0.00110	0.00107	0.00103	0.00091	0.00113	0.00123	0.00114	0.00119	0.00136	0.00118
7	0.00106	0.00102	0.00099	0.00088	0.00108	0.00118	0.00110	0.00114	0.00131	0.00113
8	0.00101	0.00097	0.00094	0.00084	0.00103	0.00113	0.00105	0.00109	0.00126	0.00108
9	0.00095	0.00092	0.00089	0.00080	0.00098	0.00107	0.00100	0.00104	0.00120	0.00103
10	0.00089	0.00085	0.00083	0.00075	0.00091	0.00101	0.00094	0.00097	0.00113	0.00097
11	0.00081	0.00078	0.00075	0.00069	0.00084	0.00092	0.00086	0.00089	0.00104	0.00089
12	0.00071	0.00069	0.00067	0.00061	0.00074	0.00082	0.00076	0.00079	0.00093	0.00079
13	0.00060	0.00057	0.00056	0.00052	0.00062	0.00070	0.00065	0.00066	0.00080	0.00067
14	0.00045	0.00043	0.00043	0.00041	0.00047	0.00054	0.00051	0.00051	0.00064	0.00052

TABLE 3: Overturning moment (ZONE IV)

Sty.	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
0	120840	114672	100007	78406	102224	88303	74918	83088	84111	88269
1	108500	102848	89784	70504	91783	79400	67169	74669	75723	79276
2	96672	91493	79966	62948	81776	70887	59724	66617	67731	7064
3	85336	80604	70519	55710	72187	62734	52585	58909	60094	62416
4	74454	70159	61407	48749	62982	54897	45739	51511	52757	54500
5	63983	60132	52611	42032	54127	47333	39174	44383	45662	46884
6	53909	50520	44139	35543	45608	40020	32887	37505	38777	39550
7	44253	41347	36030	29289	37442	32970	26896	30885	32099	32510
8	35076	32674	28358	23309	29682	26226	21238	24563	25667	25807
9	26492	24604	21233	17680	22422	19876	15981	18616	19561	19523
10	18670	17288	14806	12510	15805	14053	11220	13165	13912	13781
11	11820	10912	9252	7950	10007	8922	7075	8364	8890	8739
12	6196	5702	4778	4183	5246	4688	3692	4399	4705	4588
13	2130	1953	1617	1440	1803	1614	1261	1515	1633	1577
14	0	0	0	0	0	0	0	0	0	0

TABLE 4: MAX. STORY DISPLACEMENT (MM) (ZONE V)

STOREY	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
1	10.20	9.805	19.75	6.67	10.24	10.97	9.59	10.43	11.48	10.22
2	16.04	15.42	25.08	11.20	16.19	17.33	15.41	16.60	18.39	16.28
3	21.64	20.84	30.13	15.70	21.90	23.45	21.07	22.57	25.10	22.15
4	26.95	25.98	34.96	20.05	27.34	29.30	26.49	28.27	31.54	27.76
5	31.96	30.82	39.55	24.21	32.48	34.84	31.66	33.67	37.67	33.08
6	36.66	35.36	43.90	28.16	37.31	40.07	36.55	38.75	43.47	38.09
7	41.04	39.59	47.98	31.88	41.82	44.98	41.16	43.52	48.95	42.80
8	45.10	43.51	51.80	35.36	46.00	49.56	45.46	47.96	54.07	47.19
9	48.82	47.11	55.32	38.59	49.85	53.79	49.46	52.06	58.84	51.25
10	52.19	50.36	58.54	41.55	53.35	57.65	53.12	55.80	63.21	54.96
11	55.18	53.25	61.41	44.22	56.46	61.12	56.42	59.15	67.16	58.29
12	57.75	55.73	63.91	46.55	19.15	64.15	59.30	62.06	70.64	61.20
13	59.85	57.76	65.99	48.52	61.37	66.67	61.73	64.48	73.59	63.63
14	61.42	59.28	67.62	50.08	63.05	68.64	63.70	66.35	75.99	65.51

Table 5: max. story drift (ZONE V)

Sty.	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
1	.00196	.00189	.00210	.00141	.00199	.00212	.00191	.00204	.00227	.00200
2	.00195	.00188	.00179	.00152	.00198	.00212	.00194	.00206	.00231	.00202
3	.00188	.00182	.00171	.00151	.00192	.00206	.00190	.00200	.00226	.00197
4	.00181	.00175	.00166	.00147	.00185	.00199	.00184	.00193	.00219	.00191

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5	.00173	.00167	.00160	.00142	.00177	.00192	.00177	.00186	.00211	.00184
6	.00166	.00160	.00155	.00137	.00170	.00184	.00171	.00179	.00204	.00177
7	.00159	.00153	.00148	.00132	.00163	.00177	.00165	.00172	.00197	.00170
8	.00151	.00146	.00142	.00126	.00155	.00170	.00152	.00164	.00189	.00163
9	.00143	.00138	.00134	.00120	.00147	.00161	.00150	.00156	.00180	.00155
10	.00133	.00128	.00125	.00128	.00137	.00151	.00141	.00146	.0017	.0014
11	.00122	.00117	.00113	.00103	.00126	.00139	.00129	.00134	.00156	.00133
12	.00107	.00103	.00100	.00092	00111	.00124	.00115	.00119	.00140	.00119
13	.00090	.00086	.00084	.00078	.00093	.00104	.00097	.00100	.00120	.00100
14	.00068	.00065	.00065	.00062	.00071	.00081	.00079	.00077	.00096	.0007

TABLE 6: overturning moment (ZONE V)

STORY	R	D1	D2	D3	R1	R2	R3	DR1	DR2	DR3
0	181261	172009	150011	117609	153336	132455	112377	124633	126167	132404
1	162751	154272	134676	105756	137675	119101	100753	112004	113585	118915
2	145009	137240	119949	94423	122665	106331	89587	99925	101596	105996
3	128005	120906	105778	83565	108280	94101	78878	88364	90141	93624
4	111681	105238	92110	73124	94473	82346	68609	77267	79135	81750
5	95975	90199	78917	63049	81190	71000	58761	66575	68494	70326
6	80864	75780	66209	53315	68412	60031	49331	56258	58166	59325
7	66379	62021	54046	43933	56163	49455	40344	46328	48149	48765
8	52614	49012	42537	34964	44523	39339	31857	36844	38500	38710
9	39738	36907	31850	26520	33633	29815	23971	27924	29341	29284
10	28006	25932	22209	18765	23707	21080	16830	19748	20869	20672
11	17730	16368	13878	11925	15011	13383	10612	12546	13336	13109
12	9294	8553	7168	6275	7870	7032	5538	6598	7057	6882
13	3195	2929	2426	2160	2704	2421	1892	2273	2449	2366
14	0	0	0	0	0	0	0	0	0	0

TABLE 7: Base shear

S.No.	MODELS	BASE SHEAR (ZONE IV)	BASE SHEAR (ZONE V)
1	R	4076.3465 KN	6114.519 KN
2	D1	3872.2100 KN	5808.310 KN
3	D2	3312.7800 KN	4969.170 KN
4	D3	3690.9300 KN	5536.400 KN
5	R1	3506.9188 KN	5260.370 KN
6	R2	3122.2062 KN	4683.300 KN
7	R3	2696.8046 KN	4045.200 KN
8	DR1	3074.9743 KN	4612.46 KN
9	DR2	3165.2912 KN	4747.937 KN
10	DR3	3160.2926 KN	4740.438 KN

GRAPH

ZONE IV

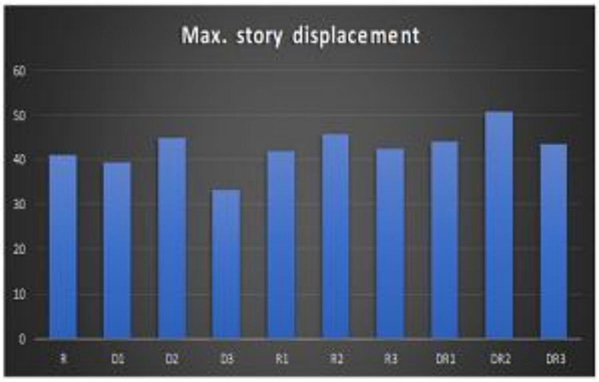

Fig. 13: Max. story displacement

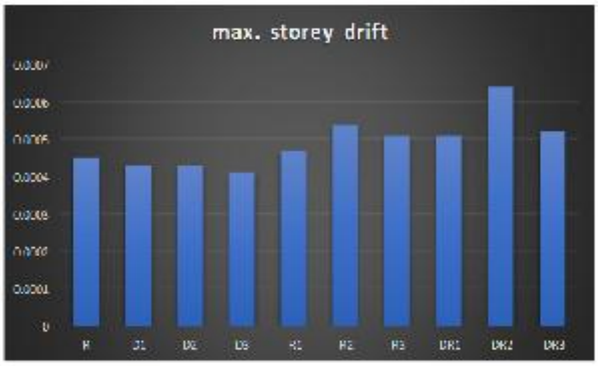

Fig. 14: max. story drift

Fig. 15: Overturning moment

ZONE V

Fig. 16: max. story displacement

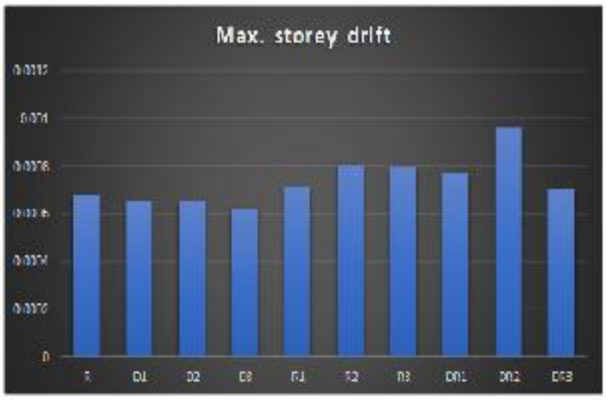

Fig.17: max. story drift

Fig. 18: overturning moments

Fig. 19: base shear

VII. CONCLUSION

Seismic response of plan irregular building in two different zones IV and V are studied. After study of results obtained from the analysis of structure, following conclusion can be made-

1) For base shear (refer table 7 and fig. 19), regular building shows max. lateral force at the base. Irregular plan building shows decrease in the value f base shear when percentage of irregularity increases. But when it comes combined irregular building model DR2 shows max. base shear. Hence, we can also say weight of building also effects base shear, more weight more base shear.

2) For max. displacement (fig. 16 and 13), model DR2 shows maximum for both zones.and model D3 show least displacement. By this we can say that diaphragm opening not much effect the displacement but re-entrants do. And combination of both makes structure more unstable.
3) When it comes to story drift (refer Fig. 14 and 17) from results, we can see that more percentage of opening less drift value and more varying percentage re-entrant more drift. Therefore, when it comes to the combination of two models DR2 shows max. drift for both zones.
4) Models R shows max. overturning moment (refer fig. 18 and 15) and as opening in slabs increases it reduces. Similarly, it is for re-entrant corner models. But for the combination of two irregularity there is an increase in overturning moment as varying percentage increases. Hence, we can say that large slab opening results in less overturning moment.

Hence, it can be seen that due to more weight of the building base shear and overturning moment is more and due to unsymmetry of the structure max. displacement and story drift is more.

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