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A PARAMETRIC STUDY ON THE SIESMIC PERFORMANCE OF FLAT SLAB MULTI-STORIED BUILDING WITH BRACINGS SUBJECTED TO IRREGULARITIES

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Abstract – *Flat slab building tends to have lower performances in the seismic region, also During an earthquake the movement induced has the effect at the point of the location of the irregularities which may be geometric, stiffness, torsional. To strength the structures the lateral load resisting system must be provided. Lateral resistance can be provided by Bracing. The core objective is to study the performance of the multi-storied flat slab structures with Bracings subjected to vertical geometric irregularities, stiffness irregularities, & torsional irregularities. For the analysis response spectrum method is carried out in ETABS 2017.*

10-storey building is modeled for the analysis and the parameters used for the comparison are storey stiffness, storey drift, time period, storey displacement & Base shear.

Key Words: *Stiffness, torsion, flat slab, time period, Bracing, Irregularity, ETABS.*

1. INTRODUCTION

The intricacy of seismic tremor ground movement is essentially because of the variables, for example, the source impact, way impact and neighbourhood site impact. Seismic tremor makes the ground vibrate and thusly the structures bolstered on them are exposed to movement. Accordingly, the dynamic stacking on the structure during a tremor isn't an outer stacking, however a stacking emerging because of the movement of ground. A portion of the components adding to the auxiliary harm during quakes are plan and vertical irregularities, irregularities in mass, stiffness & torsional irregularities and so on. Structure with straightforward normal shape and uniform distributed mass and having regular symmetric plan are considered to endure a lot lesser harm than structures with unpredictable structure. However, these days, unpredictable structures are favoured due to their useful and stylish contemplations is obvious from instances of reasonable existing sporadic structures

1.1 FLAT SLAB

Normal practice with regards to design and construction is that the slabs are supported by beam and beam by column. This is known as beam-slab construction yet for these situation the net clear height is been diminished. Therefore, in public buildings, warehouses and malls the slabs are directly reinforced to columns. This type of construction is very economical and gives good appealing presences. Such kind of construction in which slabs are directly rested in columns are called flat slabs.

TYPES OF FLAT SLABS:-

- Simple flat slab
- Flat slab with drop panels
- Flat slab with column heads
- Flat slab with both drop & column head

IMPORTANCES OF DROP PANELS:

- Resists higher bending moments.
- Stiffening of slab & reduction in deflection
- Shear strength of slab is increased

Fig -1: Flat slab with Drop Panel

ADVANTAGE OF FLAT SLABS:

It is perceived that construction of flat slab without drop can be carried out at faster rate due to simplicity in formwork. Likewise, faster construction can be accomplished utilizing an arrangement utilizing early striking and flying frameworks.

Flat slab building can profoundly diminish floor-to-floor height particularly in absences of false ceiling acts as limiting factor on the placement of partitions and horizontal services.

In the event that the customer revised the plan in the inside & needs to utilize the convenience to meet their need, flat slab construction is the ideal decision as it provides suppleness to the proprietor.

2. LITERATURE REVIEW

"S. Praveen Kumar, G. Augustine maniraj pandian"(2016) [1] Conducted the study on Evaluation & analysis on structural system with the provisions of bracing and shear wall. It concludes steel bracing of X type contributes to structural stiffness, storey drift & lateral displacement due to seismic motions is reduced, shear walls are provided for resisting the lateral forces and gravity load, positioning of shear-wall plays as important part in behaviour of structure as it has high in plane stiffness. For Analysis ETABS is used for determination of effective lateral load resisting system. Evaluation is carried out in terms of parameters storey drift, base shear, time period, storey displacement. The Aim of study was to compare rigid braced frame structure & RCC shear wall structure.

3. METHODOLOGY:

The modeling of building is carried out in ETABS 2017 version. This building is modelled with flat slab element and is being subjected to the irregularities.

Building with 5bays in both direction is considered with each bay of 5m.

Building with total height of 35m with each storey height being 3.5m is considered for vertical geometric irregularity, regular building & torsional irregularity.

For stiffness irregularity the storey height of 7m is considered at level 4, for G+8 storey building.

Note: building height is kept same i.e. 35m for the ease in calculations.

Defining Material Properties:

It's the important aspect both the steel and concrete properties needs to be defined.

Grade of Concrete: M20

Grade of Steel: Fe415

Density of RCC: 25KN/m^3

Steel Section Grade: Fe250

Defining Material Sections:

Columns:

All columns have square cross section of equal size of 600mm X 600mm.

Slab:

Slab thickness of 200mm having drop panel of size

2.5m X 2.5m of 75mm thickness is used as the floor element.

Lateral load Resisting System:

Bracing is provided as the lateral load resisting system, for bracing back to back angle of ISA 200x200x15mm is used.

Loads Considered:

Three kinds of primary load cases as per Indian standard provisions:

Dead Load (IS 875(part I)-1987)

Live Load (IS 875(part II)-1987)

Seismic Load (IS 1893(part III)-2002).

Gravity load:

Imposed load of 4KN/m^2 and the floor finish of 2KN/m^2 is considered on the entire floor level.

Seismic Parameters:

- Earthquake Zone (Z) = III
- Response-Reduction Factor (RF) = 3 (OMRF)
- Importance factor 'i' = 1.5
- site factor for rock & soil (SS) = II (Medium soil)
- Structure Type = 1 (RC Structure)
- Ratio of Damping = 0.05

3.1 MODEL DETAILS

Analysis carried out for models is by Response Spectrum Analysis which is Linear Dynamic Analysis: -

The Distinct models considered are generated using ETABS 2017 Version.

o Flat-Slab Structure with Bracing.

Following above system is modelled with following conditions: -

- Symmetric building.
- Vertical Geometric Irregularity.
- Stiffness Irregularity.
- Torsional Irregularity.

analysis is carried out by Response spectrum and following parameters are obtained: -

- Story Displacements
- Story Drift
- Base shear
- Story Stiffness
- Time Period

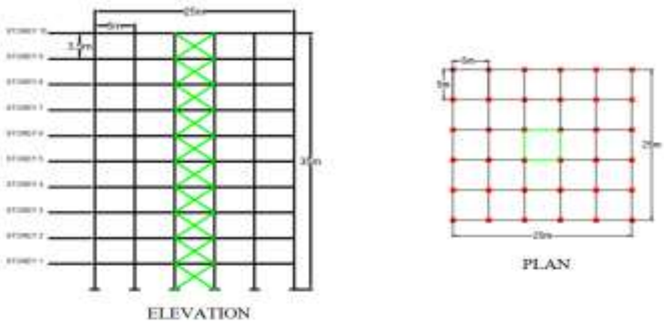

Fig -3.1: MODEL-C1 REGULAR FLAT SLAB BUILDING WITH BRACINGS

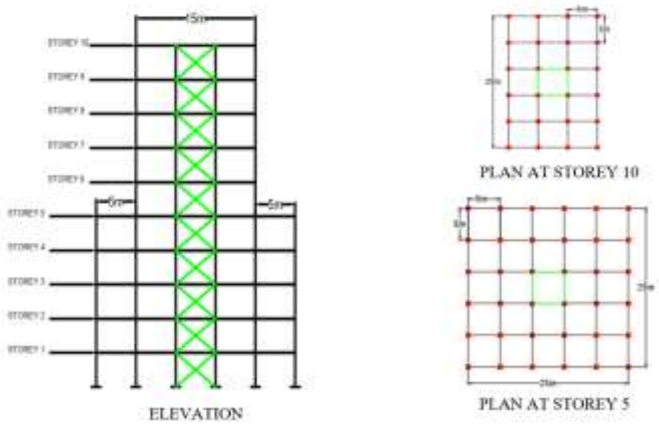

Fig -3.2: MODEL-C2 GEOMETRIC IRREGULARITY-FLAT SLAB BUILDING WITH BRACINGS

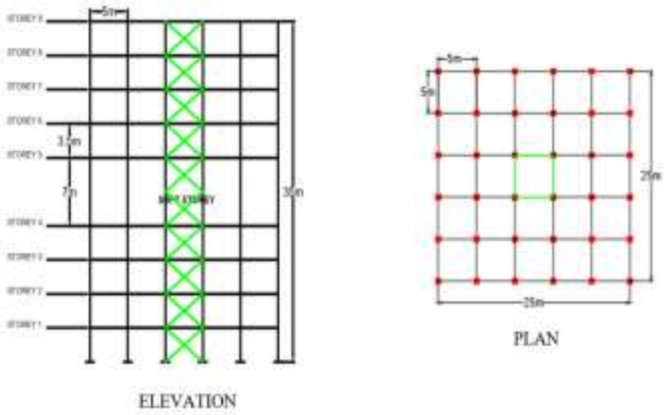

Fig -3.3: MODEL-C3 STIFFNESS IRREGULARITY-FLAT SLAB BUILDING WITH BRACINGS

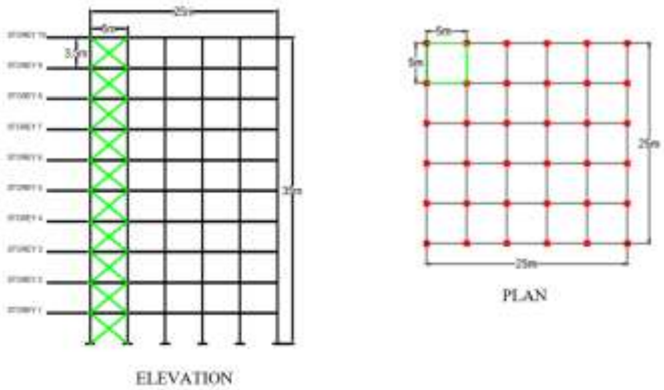

Fig -3.4: MODEL-C4 TORSIONAL IRREGULARITY–FLAT SLAB BUILDING WITH BRACINGS

ETABS MODELING:

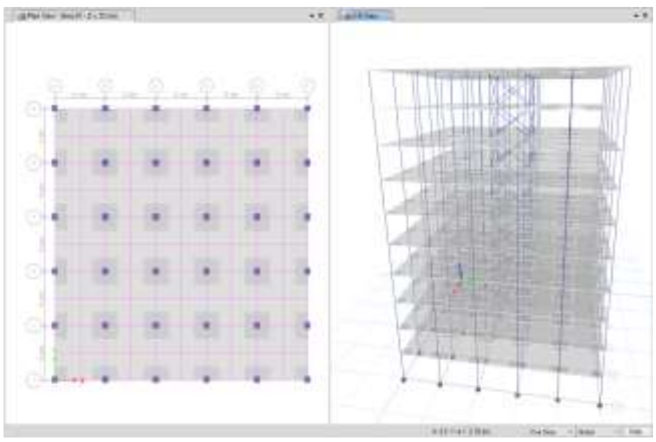

Fig -3.5: MODEL-C1 REGULAR FLAT SLAB BUILDING WITH BRACINGS

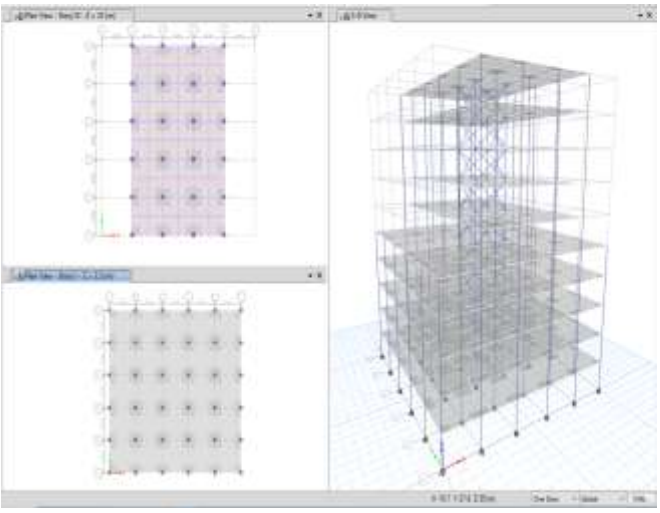

Fig -3.6: MODEL-C2 GEOMETRIC IRREGULARITY-FLAT SLAB BUILDING WITH BRACINGS

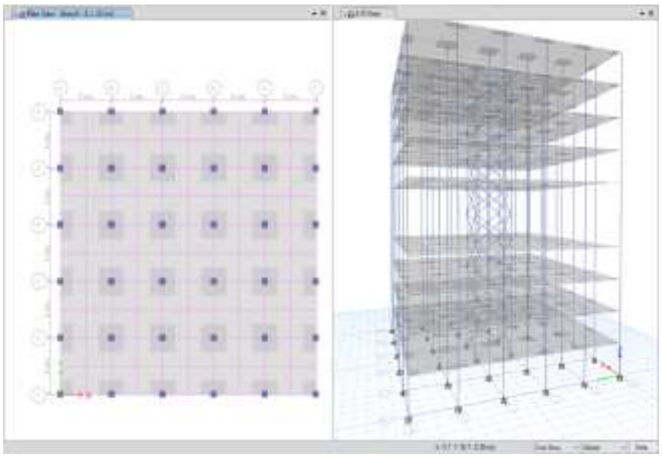

Fig -3.7: MODEL-C3 STIFFNESS IRREGUALRITY-FLAT SLAB BUILDING WITH BRACINGS

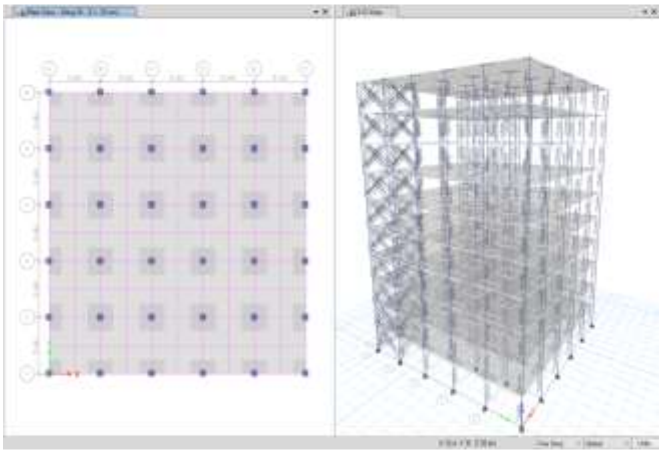

Fig -3.8: MODEL-C4 TORSIONAL IRREGULARITY–FLAT SLAB BUILDING WITH BRACINGS

4. RESULTS & DISCUSSIONS

STOREY DISPLACEMENT:

Table -4.1: Storey Displacement at each level.

STOREY	Elevation	MODEL C1	MODEL C2	MODEL C3	MODEL C4
	in meters	in mm	in mm	in mm	in mm
STOREY10	35	24.378	26.181	27.911	30.4
STOREY9	31.5	22.345	23.709	25.578	28.86
STOREY8	28	20	20.949	22.884	26.819
STOREY7	24.5	17.444	18.022	19.935	24.282
STOREY6	21	14.727	15.002	16.772	21.302
STOREY5	17.5	11.908	12.034	-	17.916
STOREY4	14	9.053	9.199	9.717	14.147
STOREY3	10.5	6.247	6.385	6.659	10.056
STOREY2	7	3.611	3.716	3.834	5.834
STOREY1	3.5	1.318	1.366	1.395	2.004
Base	0	0	0	0	0

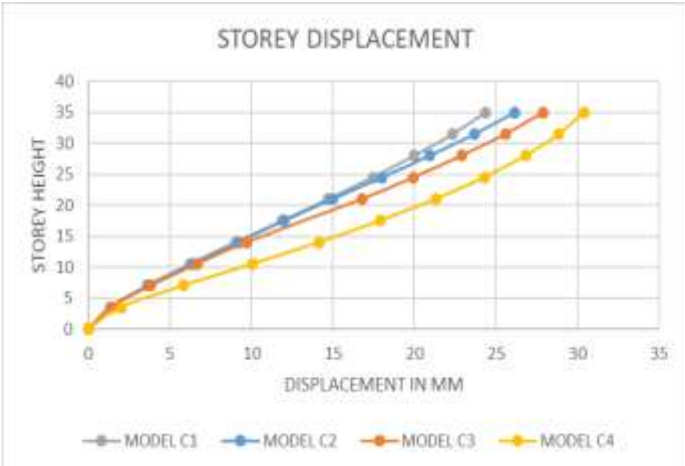

Fig -4.1: Storey displacement of Structure

- ✓ Linear variation in the curve of Storey displacement can be observed for all the models, with the maximum in the MODEL-C4.
- ✓ In the case of MODEL-C4 maximum Storey displacement is due to torsional irregularity.
- ✓ The Storey displacement is increased by 24% in MODEL-C4 in comparison to MODEL-C1. The storey displacement in MODEL-C2 & MODEL-C3 are increased by 7% & 14% respectively w.r.t. MODEL-C1.

- ✓ Storey displacement could be reduced marginally with the provision of Lateral Load resisting system in terms of bracings.
- ✓ Structure with regular symmetric plan seems to have undergone lesser storey displacement w.r.t. the other models.

STOREY DRIFT: -

Table -4.2: Storey Drift at each level.

STOREY	ELEVATION	MODEL C1	MODEL C2	MODEL C3	MODEL C4
	in meters	in mm	in mm	in mm	in mm
STOREY10	35	0.00058	0.00071	0.00067	0.00044
STOREY9	31.5	0.00067	0.00079	0.00077	0.00058
STOREY8	28	0.00073	0.00084	0.00084	0.00072
STOREY7	24.5	0.00078	0.00086	0.00090	0.00085
STOREY6	21	0.00081	0.00085	0.00101	0.00097
STOREY5	17.5	0.00082	0.00081	-	0.00108
STOREY4	14	0.00080	0.00080	0.00087	0.00117
STOREY3	10.5	0.00075	0.00076	0.00081	0.00121
STOREY2	7	0.00066	0.00067	0.00070	0.00109
STOREY1	3.5	0.00038	0.00039	0.00040	0.00057
Base	0	0.00000	0.00000	0.00000	0.00000

Fig -4.2: Storey drift of Structure

- ✓ From MODEL-C1, the variation in storey drift is uniform when two adjacent storeys are taken into consideration.
- ✓ From MODEL-C3, there is sudden change in storey Drift at the levels where the soft storey is located.
- ✓ For MODEL-C2 there sudden change in storey Drift at the levels where there is change in vertical geometry of the structures.
- ✓ In MODEL-C4 Larger storey drift is observed at the lower level and its reduces at top marginally due to torsional irregularity.
- ✓ storey drift increases with the irregularities in the structures & sudden increase is seen from the point of location of the irregularities.
- ✓ Bracing doesn't seem to be effective in resisting storey drift in comparison to shear wall.

BASE SHEAR: -

Table -4.3: Maximum Base shear

RESULTS: -	MODEL-C1	MODEL-C2	MODEL-C3	MODEL-C4
BASE SHEAR IN KN	1875.1732	1963.3923	1960.2964	1258.091

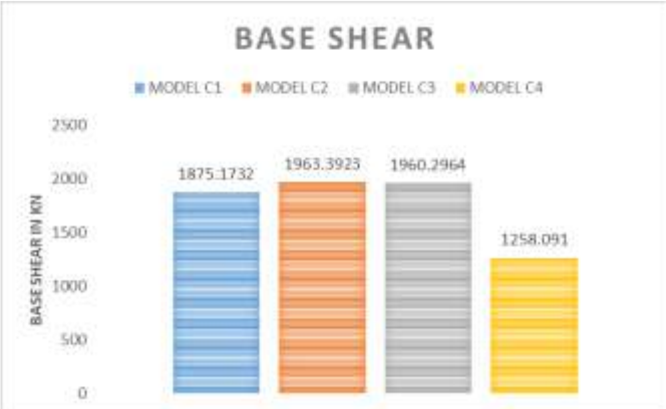

Fig -4.3: Base shear of Structure

- ✓ Maximum expected lateral force is in MODEL-C2 &C3 as the Base Shear is high.
- ✓ Least base shear is observed in MODEL-C4, which is due to change in bracing location i.e. by placing at one end corner.
- ✓ From MODEL-C1 & C4, location of Bracing plays an significant role in terms of Base-Shear. Bracing at the centre of building will have higher base shear as in MODEL-C1 compared to Bracing at the one end corner as in case in MODEL-C4.
- ✓ Base shear can be reduced by using Bracing instead of shear wall by 34%.

STOREY STIFFNESS: -

Table -4.4: Storey Stiffness at each Level.

STOREY	ELEVATION	MODEL C1	MODEL C2	MODEL C3	MODEL C4
	m	KN/M	KN/M	KN/M	KN/M
STOREY10	35	215771.3	155299.5	206331.8	174584.6
STOREY9	31.5	319153.1	486688.1	302572.4	243449.8
STOREY8	28	367742.8	583734.1	344998.6	266993.0
STOREY7	24.5	397423.2	648477.5	367699.4	277743.9
STOREY6	21	425987.7	151169.4	155806.6	288174.9
STOREY5	17.5	467611.2	437840.7	-	304447.0
STOREY4	14	532253.5	515749.2	485312.3	330347.1
STOREY3	10.5	628935.4	627155.5	598526.8	370779.9
STOREY2	7	785968.2	794147.8	769210.4	453339.1
STOREY1	3.5	1422393.9	1437184.2	1412651.1	873735.6
Base	0	0.0	0.0	0.0	0.0

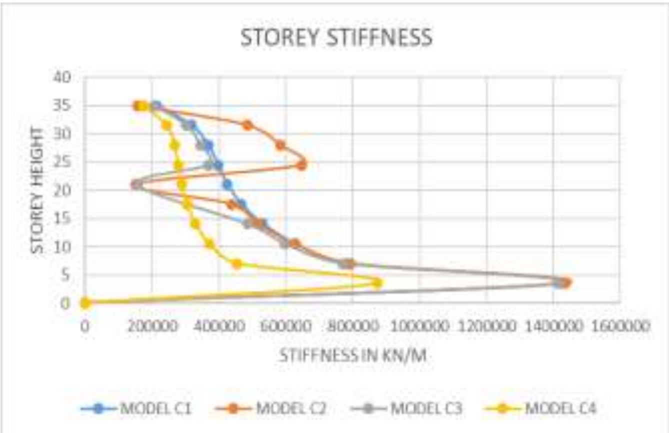

Fig -4.4: Stiffness Variation along the height of structure

Storey stiffness: -

- ✓ In MODEL-C1 & C4 the story stiffness pattern observed is uniform. The large stiffness variation is seen in MODEL-C2 & C3 at site of change in the vertical geometry and at the location of soft storey.
- ✓ From MODEL-C2& C3 it is noticed that the stiffness of the structure is decreased due to soft storey and change in vertical geometry.
- ✓ Storey stiffness of floor at the level of change in vertical geometry of MODEL-C2 and at level of soft storey location in MODEL-C3 is 64% w.r.t to the adjacent upper storey.
- ✓ Model C4 has the lowest story stiffness which varies uniformly. Hence its more prone to the seismic effects. Due to torsional irregularity the stiffness of the structure is decreased.
- ✓ There is larger stiffness reduction due to the Geometric irregularity than stiffness irregularity.

TIME PERIOD:

Table-4.5: time period for various modes.

TIME PERIOD	MODEL C1	MODEL C2	MODEL C3	MODEL C4
Modal case	Period	Period	Period	Period
	sec	sec	sec	sec
1	1.724	1.293	1.754	2.022
2	1.475	1.257	1.506	1.533
3	1.475	1.252	1.505	1.097
4	0.548	0.531	0.519	0.631
5	0.421	0.404	0.392	0.428
6	0.421	0.403	0.392	0.343
7	0.302	0.269	0.316	0.29
8	0.213	0.194	0.218	0.218
9	0.213	0.194	0.218	0.214
10	0.194	0.188	0.175	0.15
11	0.14	0.131	0.141	0.142
12	0.14	0.131	0.128	0.14

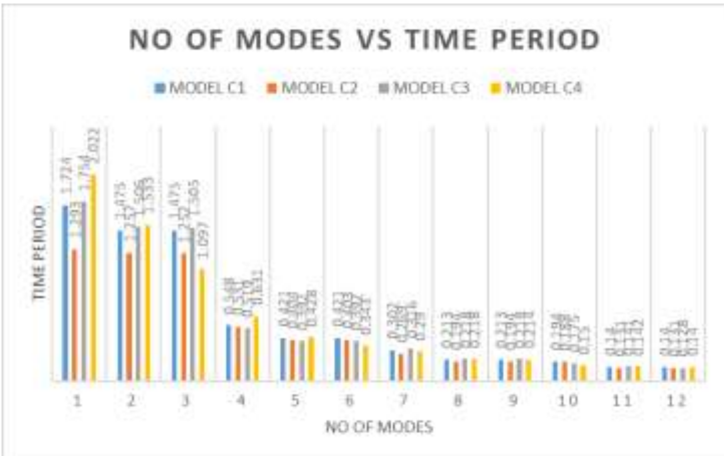

Fig -4.5: No of modes Vs Time Period.

Time Period: -

- ✓ Time period is in range of 0.05-2sec for single to 20 storey building.
- ✓ Value of Time period is governed by the flexibility and mass therefore higher is the Time period if mass is more.
- ✓ MODEL-C2 has the lowest time period of 1.29 sec, as lesser the mass lesser is the time period.
- ✓ MODEL-C4 has maximium time period is 2.02 sec because of torsional irregularity.
- ✓ MODEL-C1 & C3, has nearly equal time period of 1.74 sec for modal case 1.

5. CONCLUSIONS

- ✓ Structure subjected to the geometric vertical irregularities, stiffness irregularities and torsional irregularities have linear storey displacement curve.
- ✓ Stiffness of the structure is decreased at the level of change in vertical geometry and at the location of the soft storey.
- ✓ Structure subjected to torsional irregularities has the uniform lower stiffness with respect to other model.
- ✓ In soft storey models, the storey drift at the level of location of soft storey is higher. Its due to the fact that soft storey has lower stiffness which attract larger lateral forces because of which it undergoes large deflection due to lateral forces.
- ✓ For many conditions It is settled that lateral forces is resisted by steel bracing in flat slab construction.

6. SCOPE FOR FUTURE STUDIES

- ✓ Performance of Flat slab structure in seismic regions for different properties of Bracings and types of Bracings such as V, X, inverted V, Diagonal Bracings etc.

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