SEISMIC RESPONSE OF MULTISTOREY FLAT SLAB BUILDING WITH AND WITHOUT SHEAR WALL

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Abstract -*A popular form of concrete building construction uses a flat concrete slab (without beams) as the floor system. This system is very simple to construct, and is efficient in that it requires the minimum building height for a given number of stories. The flat slab system is currently widely used in construction. It permits flexibility in architecture, more clear space, low building height, easier formwork, and shorter construction time. However, Flat slab building structures are significantly more flexible than traditional concrete structures as beams are not present. They are more vulnerable to earthquakes. The objective of this research is to investigate the behavior of flat slab multistory G+19 building in four different cases as I) flat slab structure without shear wall. II) Flat slab structure with shear wall at core of the building. III)Flat slab structure with shear wall at corners of the building IV). Flat slab structure with shear wall at side centers of the perimeter boundary of the building. The lateral behavior of a typical flat slab building is evaluated by means of dynamic analysis through linear time history analysis method using ETABS software. The efficiency and serviceability under Indian standard code in seismic zone 'V' been observed for each defined model and compared the values with international codes.*

***Key Words*: Flat slab, Shear wall, ETABs, Linear Time history Analysis**

1. INTRODUCTION

An earthquake (also known as a quake, tremor or temblor) is the shaking of the surface of the Earth, which can be violent enough to destroy major buildings and kill thousands of people. Earthquake has been known as one of the critical natural disasters for thousands of years. Recent major earthquakes have caused severe social disruption in the territory of the epicenter, especially due to structural failures causing damage to the people and properties. Flat slab is provided in malls, theatres and other structures where large beam free spaces are required. Shear walls are needed for flat slab construction, when earthquake resistance is considered. Flat slab structures in areas of low seismicity (Zone II) can be designed to resist both vertical and lateral loads as permitted by code IS 1893 Part1:2002. However for areas of high seismicity (Zone III, IV & V) code does not permit flat slab construction without any lateral load resisting system or lateral force resisting system. In this research work, modeling and study of seismic response along with earthquake forces on twenty storey (G+19) flat slab multi-storey building in absence and presence of shear wall had been done. Shear wall is placed at core of the building then at the outer corners and finally at the center of the outer perimeter walls, then efficiency and serviceability under Indian standard conditions in seismic zone 'V' been observed for each defined model.

1.1 Flat Slab

Flat slab are preferential by both architects and clients because of their aesthetic and economic advantages. Though this form of reinforced concrete construction gives several advantages over framed structure, there are also some disadvantages because of brittle punching failure at slab column junction and large deformation in horizontal direction. Many researches propose that flat slab should be designed to resist only gravity loads when used in higher seismic zones and lateral loads should be carried by the lateral force resistant system. Flat slab can be supported directly by the column or by a column capital and drop panel. The performance of flat slab building under seismic loading is poor as compare to framed structure due to lack of frame action which leads to excessive lateral deformation. In flat slab building the most vulnerable part is slab column joint. Extensive research has been done to find out the behavior of flat slab column connection. The failure mode depends upon the type and extent of loading. Punching shear strength of slab column connection is important which very much depends on the gravity shear ratio. Punching failure of flat slab can occur as a result of transfer of shearing force and unbalanced moment between slab and column.

1.2 Shear Walls

Shear wall is one of the most commonly used lateral load resisting system in high rise building. Shear wall has high in plane stiffness and strength which can be used to simultaneously resist large horizontal load and support gravity load. To resist lateral force due to wind and earthquakes R.C shear walls are used in buildings. They are normally provided between column lines, in stair wells, lift wells, in shafts that house other utilities. Shear wall provide lateral load resisting by transferring the wind or earthquake load to foundation. Besides, they impart lateral stiffness to the system and also carry gravity loads. They are commonly used in tall building to avoid collapse of buildings. Shear wall may become inevitable from the point of view of economy and control of lateral deflection. When shear wall are situated in advantageous positions in the building they can form an efficient lateral force resisting system. Many building codes instruct the use of such walls to make homes safer and more stable.

Flat slab building has a column-slab system, which is expected to resist both gravity loads and earthquake-induced lateral inertia loads. Flat slab buildings have low lateral stiffness, and hence swing by large amounts of elastically even during low level earthquake shaking owing to little rotational flexibility offered by the thin slabs inter-connecting the columns. Since the column-slab system has small lateral stiffness and lateral load resistance, this large overall lateral drift of the flat slab building makes the columns incapable of accommodating the additional secondary moments generated by the lateral deformations. Thus, there are serious concerns on the use of flat slab buildings in seismic regions IV and V.

Attempts were made to compensate for this lack of capacity in the slab in flat slab buildings by reducing overall lateral deformation and thereby to improve their overall lateral resistance by adding a supplemental lateral load resisting system (LLRS) in the form of structural walls.

2. LITERATURE REVIEW

A brief review of previous studies on the performance of shear wall in flat slab buildings is presented in this section. This literature review focuses on recent contributions related to dynamic analysis of flat slab multi-storey structures and past efforts most closely related to the needs of the present work.

Vikunj k.Tilva, Prof. B.A.Vyas (2011) in their paper summarised that to avail a comparison between flat slab panel with drop and without drop in four storey lateral load resisting building. A four storey building (having 6mx6m panel) is subjected to gravity load + lateral load using ETABS (Extended 3D Analysis of Building Systems) software and each storey was exported to SAFE(Slab Analysis by the Finite Element Method) software for analyzing punching effect due to lateral loads. On the basis of permissible punching shear criteria according to IS 456, economical thickness of flat slab with drop and without drop are selected the results showed that from economic point of view slab with drop provision is preferable. Also punching shear stress is reduced by adopting drop at slab-column connection

Dr. Uttamasha Gupta, Shruti Ratnaparkhe, Padma Gome (2012) in their paper compare the behaviour of multi-storey buildings having flat slabs with drops with that of having two way slabs with beams and to study the effect of part shear walls on the performance of these two types of buildings under seismic forces. Present work provides a good source of information on the parameters lateral displacement and storey drift. For all the cases considered drift values follow a parabolic path along storey height with maximum value lying somewhere near the middle storey. Use of flat slabs with drop results in increase in drift values in shorter plans and decrease in larger plans, marginally in a range of 0.5mm to 3mm. Still all drift values are within permissible limits even without shear walls In zone III and IV use of flat slabs with drop in place of beam slab arrangements, though, alters the maximum lateral displacement values, however, these all are well within permissible limits, even without shear walls.

Sharad P. Desai, Swapnil B. Cholekar (2013) in their paper summarised that the Dynamic response of Flat slab with drop and without drop and Conventional Reinforced Concrete Framed Structures, for different height with and without masonry infill wall. Dynamic analysis for different types of building is done by using Response Spectrum method for earthquake zone III as per Indian Standard code. The effect of Flat slab with drop and Flat slab without drop considering with and without masonry infill wall is evaluated. It was found a significant change in the seismic parameters such as Fundamental Natural Period, Design Base Shear, Displacement and Axial Force of the structure.

Rajiv M S, Guru Prasad T N, (2015)in their paper presented work to compare the behavior of multi-storey buildings having flat slabs with drops to that of having two way slabs (conventional slab). The effect of part shear walls on the performance of different types of buildings [(G+7) and (G+14)] under seismic forces are studied. Equivalent static force method, Response spectrum method and Time history analysis were considered for different types of models and comparative results were drawn. The natural mode (time) period increases as the height of building (No. of stories) increases, irrespective of type of building conventional slab (bare), flat slab (bare) and flat slab with shear wall. However, the time period is more for conventional slab and flat slab with bare frame compared with that of flat slab with shear wall for different models because of stiffness participation factor is less in bare frame for both storeys. This presents a summary of the project work, for conventional R.C.C building, flat slab building and flat slab building with shear wall at different locations for different types of building [(G+7) and (G+14)] in the seismic region

Rajini .A .T , Dr. Manjunath N Hegde (2016) in their paper presented comparative study of the behaviour of flat slab and conventional slab buildings of 20 stories in different cases. Normal conventional and flat slab building, flat slab building with column drop, conventional building and flat slab building with shear walls at different locations were analyzed by considering two typical zones of zone III and zone V, through dynamic response spectrum analysis by using ETABS software. Comparing the consequences of all models in terms of time period and frequency, lateral displacements, story shear and story drifts by plotting graphs.. Flat slab building with combination of column drop and shear wall is performed very well under seismic loads to reduce the displacements and drifts with increase in stiffness of building. This paper presented a assess of the study, for conventional R.C.

Mitan Kathrotiya, Dr. Kaushal Parikh (2017) in their paper presents on the review study of the behaviour of multi storey building having conventional RC frame structure, flat Slabs and to study the effect of the buildings under the seismic forces. The structure was subjected to different loading condition in different Seismic Zone and for different Soil condition. The seismic behaviour of the flat Slab and the conventional RC building structure was obtained using various software aids. On the basis of the seismic behaviour, the performance of the structure was checked. This study includes various information on the seismic parameters like storey drift, seismic base shear, and natural time period Based on the study they conclude Lateral Displacement at middle stories level is maximum. The displacement of the flat slab structure is reduced by provision of shear wall As the no. of floor increases the lateral Displacement increases. The natural time period is increases as the numbers of floors increases. Based on review from various case studies, the following conclusions are drawn as time period is more for conventional building than flat slab building because of monolithic construction.

3. METHODOLOGY

To examine the seismic behaviour of flat slab building with and without shear wall, comparative analytical study has been carried out between the models using linear time history method. The analyses have been performed using ETAB version 16.0.1. In time history method, for the calculation of different parameters like displacement and member forces, only the maximum values are considered.

3.1 Description of the building

Table -1: Building Details

1.	Building type	Commercial building
2	Type of Frame	Flat Slab system
3	Plan dimensions	46 x 24m (X*Y)
4	No.of stories	G+19
5	Bottom Storey Height	3 m
6	Plinth level above GL	2 m
7	Floor to floor height	3 m
8	Total height of Building	60 m
9	Slab Thickness for flat slab	180 mm
10	Thickness of the drop	230 mm
11	Width of drop	2 m
12	Shear wall Thickness	200 mm
13	Column size	700 x 700 mm
14	Seismic Zone	V
15	Importance Factor (I)	1
16	Response reduction factor (R)	3
17	Soil Type	II
18	Grade of concrete (slab)	M 35
19	Grade of concrete(column)	M 40
20	Unit weight of concrete	25 KN/m3
21	Damping	0.05
22	Live load	3 KN/m2
23	Floor finish	1 KN/m2
24	IS Code For Concrete	IS 456-2000
25	IS Code For Earth Quake	IS 1893-2002
26	Other Code Used in Analysis	EURO 8-2004 ACI-318
27	Reinforcement	Fe415

3.2 Method used for analysis:-

3.2.1 Elastic Time History Method:

A linear time history analysis overcomes all the disadvantages of a modal response spectrum analysis provided non-linear behavior is not involving .This method requires greater computational efforts for calculating the response at discrete times. One interesting advantage of such a procedure is that the relative signs of response quantities are preserved in the response histories. This is important when interaction effects are considered among stress resultant. The analysis may be linear or non linear. Time history analysis is used to determine the dynamic response of a structure to arbitrary loading. Time history analysis obtains the structure reaction at selected time points for a defined lasting interaction.

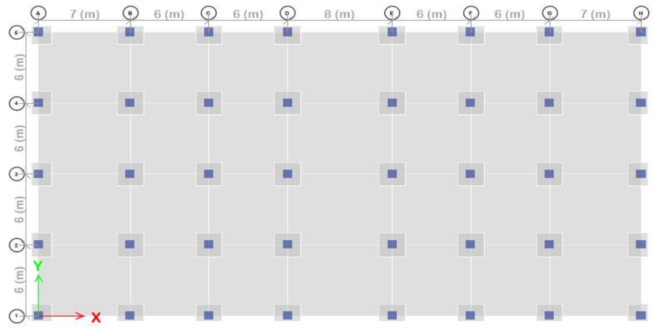
The time history analysis consists of finding a solution of the following equation of the time variable "t":

$$M * a(t) + C * v(t) + K * d(t) = F(t)$$

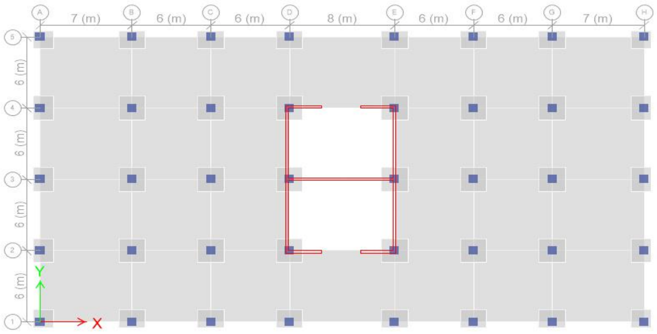
where:
M - mass matrix.
K - stiffness matrix.
C = α * M + β * K - damping matrix.
α - user defined coefficient.
β - user defined coefficient.
d - Shift vector.
v - Velocity vector.
a - Acceleration vector
F - load vector.

All expressions containing the (t) parameter are time-dependent.

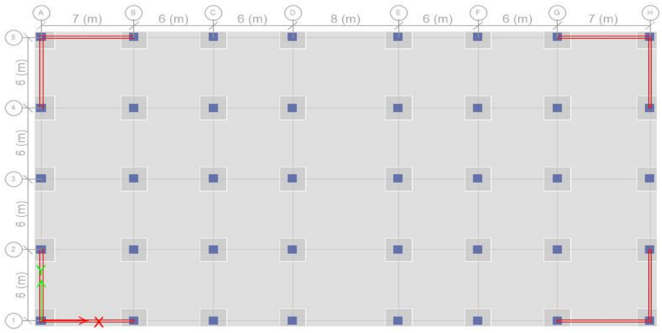
Following models were modeled using ETAB 2016 as (G+19) multi-storey commercial building-



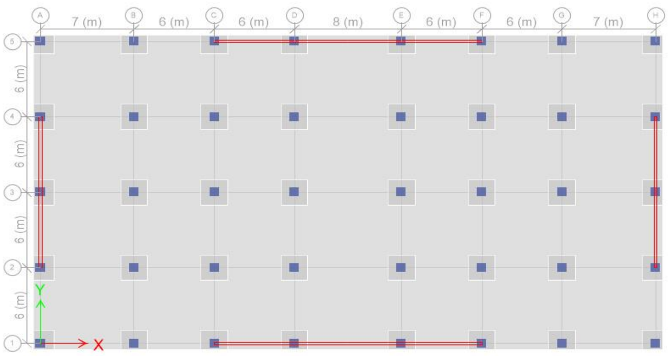
Model 1-Flat slab structure without shear wall



Model 2-Flat slab structure with core shear wall



Model 3 -Flat slab structure with corner shear wall



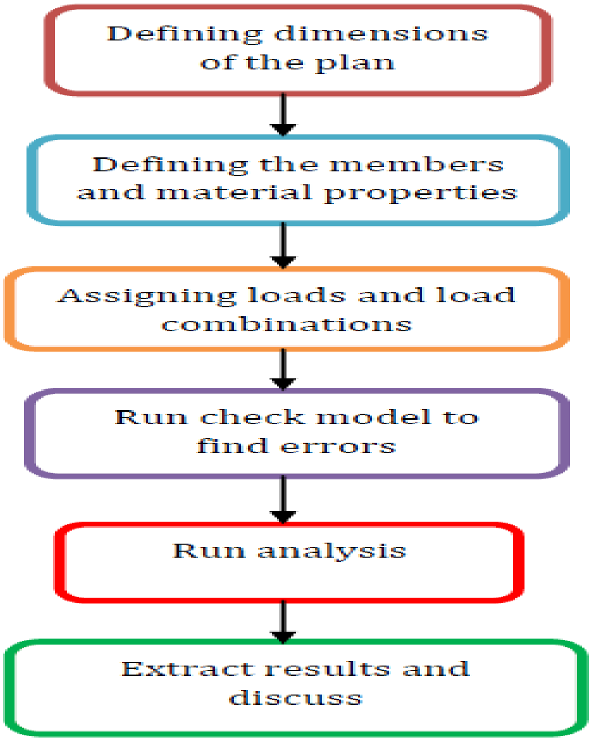
Model 4- Flat slab structure with shear wall at side center.

4. Analysis and results using ETABS software

The seismic response of the structures is investigated under earthquake excitation evaluated using time history of acceleration. The response is investigated for the structures modeled as Single Degree of Freedom (SDOF) and discrete Multi Degree of Freedom (MDOF) System.

The analysis of flat slab structure has been done by using ETABS 2016 software package. Before analysis all the required elements of the structure needs to be defined earlier like material properties, loads, load combinations, size of members, time history function etc. once the analysis has been done we can extract the results like displacement, storey shear, storey drift , drift ratio, storey stiffness for comparing the performance of all models. The flow chart shows the

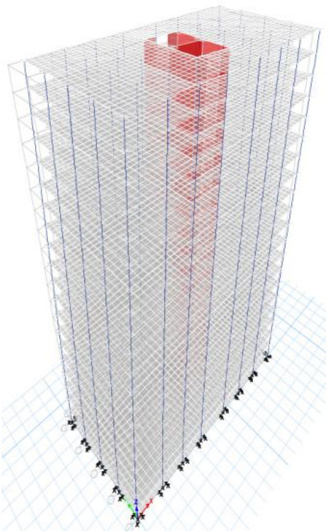
Steps involved in the analysis of ETABS.

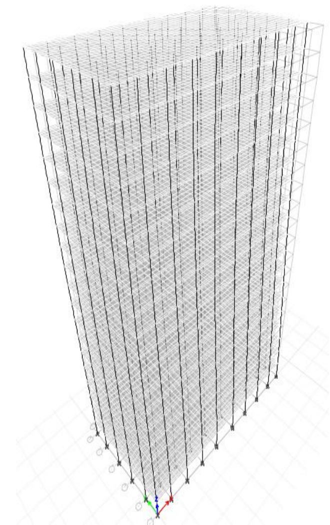


Following seismic parameters were computed for all models using Equivalent static analysis and linear time history modal analyses.

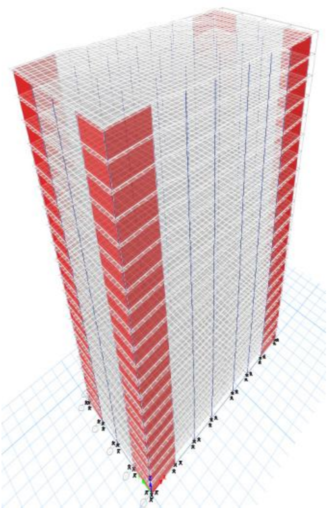
4.1 Mode shapes

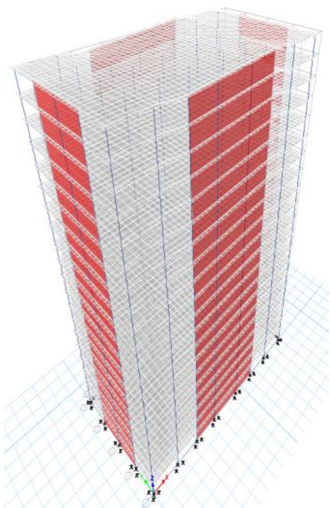
Mode 1





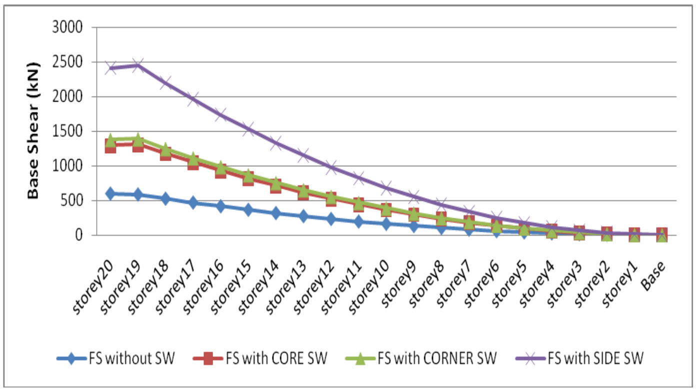
Model 1 T=4.732s **Model 2 T=1.802s**



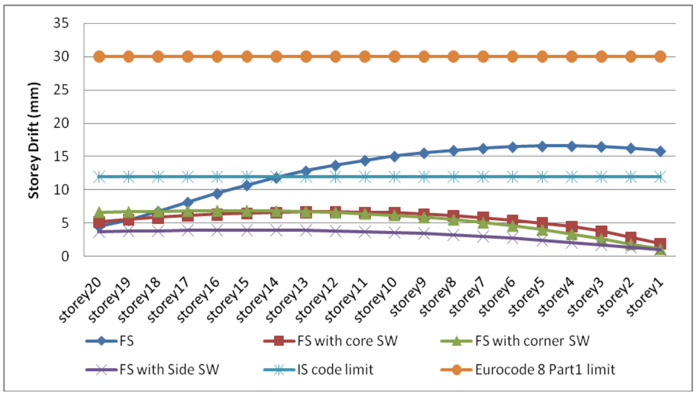


Model 3 T=1.894s **Model 4 T=1.093s**

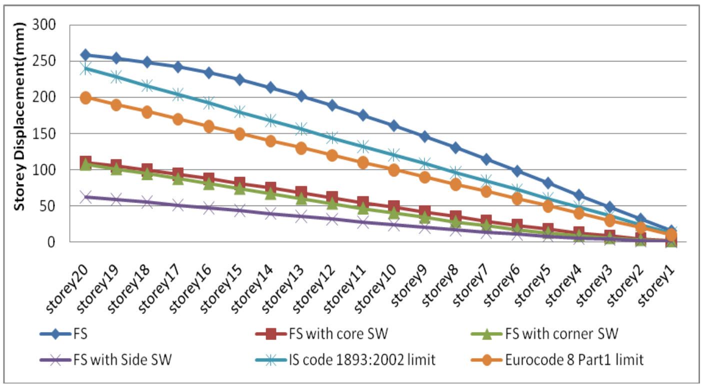
4.2 Base Shear



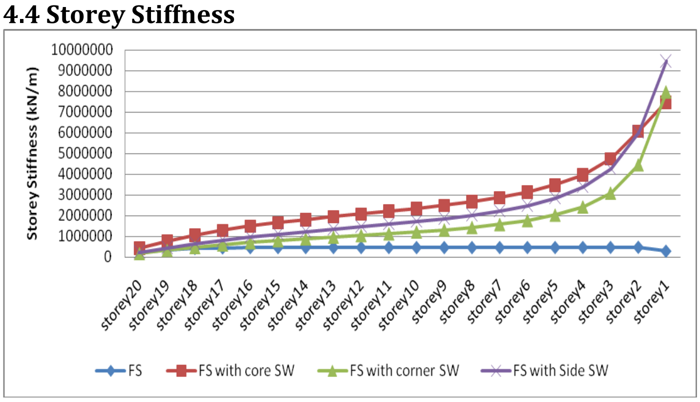
4.2 Storey Drift



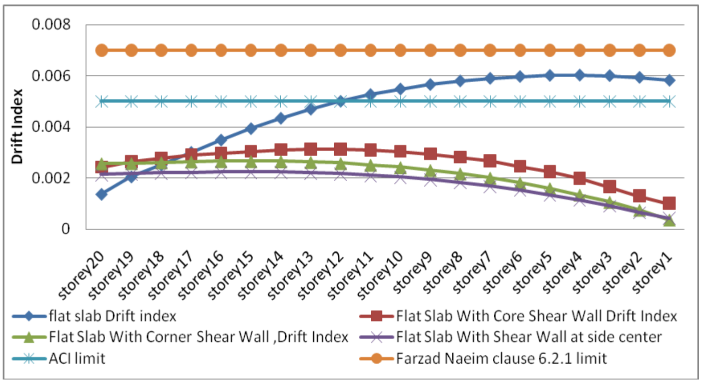
4.3 Storey Displacement



4.4 Storey Stiffness



4.5 Storey Index



5. CONCLUSIONS

This research represents the study for Flat slab multi-storey G+19 commercial building along with different location of shear wall, on the basis of analysis following conclusions have been drawn for flat slab structural framework:

1. Flat slab building without shear wall shows poor performance during earthquake excitation when compared to flat slab building with shear wall due less lateral stiffness.

2. To increase the performance of the flat-slab structure under horizontal loads, particularly when speaking about seismically prone areas modifications of such system can be done by adding structural elements such as RC shear wall.

3. The inter storey drift in flat slab without any shear wall building model as per clause 7.11.1 in IS 1893:2002 part 1 exceeds the allowable limit but as per Euro code 8 part 1 the model is safe as per defined limit. This contradict result symbolises, Indian standard permits less allowable limit with large factor of safety in earthquake resistant design with respect to International codes.

4. The concept of Storey Drift Index mentioned in Handbook By Farzad Naeim clause 6.2.1 page 171 is found to be a useful scale to testify any structural and non structural damages in the building and it has been remarked that after the addition of shear wall the value of storey Drift Index decreases which nullify the probability of any structural and non structural damages in the structure.

5. Within the limitations of this study, it is recommended that the flat slab building with shear wall at side centre should be preferred because of considerable difference in storey displacement, time period, base shear, storey drift and storey stiffness when compared to other models.

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