Comparative study on seismic analysis of conventional slab and flat slab for irregular shaped buildings: A review

Shruti A. Brahme[1], P. B. Salgar[2]

[1]P.G. Student, Dept. of Civil Engineering, Rajarambapu Institute of Technology, Islampur, Maharashtra, India.
[2] Assistant Professor, Dept. of Civil Engineering, Rajarambapu Institute of Technology, Islampur, Maharashtra, India.

Abstract - *For a building to perform well during an earthquake, its configuration is crucial. The overall geometry, structural system, and load component of a building are the key factors influencing its seismic configuration. In flat slab structures and traditional slab structures, the parameters behave differently. The design of structures is the subject of research not only in India but also in other developed nations. The building is still damaged as a result of the earthquake for many causes. Seismic load is a major component in the collapse of many high-rise buildings. Structural irregularity also adds on the seismic actions and causes devastation. To study the structural irregularity, a torsion check is covered in IS 1893:2016 part 1. In this paper, a brief review of comparison between different types of slabs and effect of structural irregularity on them is discussed. Also, the effect of various parameters like storey displacement, storey shear, storey drift, etc. on the structures is studied.*

Key Words: Conventional slab, Flat slab, Structural irregularity, Etabs software, Storey displacement, Storey drift, Storey shear.

1. INTRODUCTION

India's infrastructure facilities have grown as a result of urbanization. The land area has shrunk. This resulted in the construction of medium to high-rise buildings. Population growth puts strain on limited land space. It leads to the residential development of the city. The cost of land has risen significantly. There was also a need to reserve important agricultural production areas. All of these factors contribute to the upward trend of residential construction. Tall commercial buildings facilitate the proximity of business activities. They are also being developed in city centres as a corporate prestige symbol. High-rise buildings are now attracting both business and tourists. The slab rests on ordinary beams and columns in a conventional building. The load travels from slab to columns, columns to beams, and then beams to foundation in a conventional building. A flat slab is a concrete slab that is supported by columns at the same time without the use of beams. A flat slab is simple to build and requires little scaffolding. Flat slabs are commonly utilised in industrial and commercial structures. The seismic zone plays an important role in the construction of earthquake-resistant building structures. Storey Shear, Storey displacement, Storey drift, and Lateral forces acting on a structure have always been critical in determining the building's seismic stability.

2. LITERATURE REVIEW

The review of available literature published by various researchers in context of seismic analysis of multistorey building with different types of slabs is presented in the following section.

Farheen S. S., Rohini B. [1] studied the RCC building's structural value. A (G + 5) building structure is taken into account to examine the aim, with and without X-bracing for Rectangle, L, and T shape plan configurations. The analysis is done in ETABS. Storey displacement, overturning moment, base shear, and storey drift are the factors that are compared. According to comparable static analysis, the storey displacement is found to be within acceptable bounds and is lowest in rectangle-shaped buildings with bracing and without bracing. While T shape models with bracings recorded the lowest values for both pushover situations, L and T shape buildings were found to have the highest base shear values. Storey drift was highest in L shape building and least in rectangular in equivalent static analysis.

Bidreddy, R.S., Sanni, S.H. [2] considered a G+12 storey building for study and it is assumed that this building is present on both flat ground and on sloping ground having inclination 20 °. The models also have two alternate shear wall configurations and infill walls. Additionally, the models have a soft storey structure. As a result, a total of ten models are produced for analysis. Similar static analysis is done in this case for the study. All of the models' drift values fall within acceptable bounds. Therefore, all models with a 20 ° sloping angle are secure and within the legal bounds. The author came at the additional conclusion that adding brick and shear walls to the models would reduce displacement. Also, the observed parameters like displacement, drift, base shear, and time period are found to be maximum in bare frame model.

Mahesh Kumar, C.L., Shwetha, K.G. [3] examined the stability of flat slabs, post-tensioned slabs, and waffle slabs in this study by taking into account the shear characteristics, deflection parameters, and their behavior under seismic static and dynamic stresses. Using the finite element analysis programs ETABS and SAFE, effects on lateral displacement, storey shear, storey stiffness, punching shear, short-term, and long-term deflection have been investigated. In comparison to ribbed slab, flat slab and post-tensioned slab require a larger drop size. When comparing flat and ribbed slabs, the displacement is greater for the post-tensioned slab and less for the latter. Storey shear is high in case of flat slab and storey stiffness is also high in case of flat slab compared to waffle and post tensioned slab.

Akshata Barkade, Prof. U.L. Deshpande [4] studied and designed a G+10 commercial building for seismic zones IV and V with several slab arrangements, such as a conventional slab, a flat slab with drop panels, and a grid/ waffle slab. Several characteristics, such as storey drift, base shear, and storey displacement, which affect the performance of the structure, play an important part in determining the structure's response to seismic stresses. In ETABS 2016, the analysis and design were done in compliance with IS 456:2000 and IS 1893:2016 using concrete of the M30 grade and steel of the FE 500 grade. The conventional slab has a 94.16% less story shear than the flat slab in seismic zones IV and V. When a structure is designed with a conventional slab, the value of base shear is 22.89% higher than when a building is designed with a flat slab.

Sridevi, Sudarshan, et al. [5] used the ETABS software to examine structures that are subjected to both seismic load and blast load. This study takes into account regular, L-shaped, and C-shaped buildings with a range of RC and composite structural heights. For the seismic analysis, the response spectrum approach is taken into account. In order to determine how the structures will react to seismic and blast loads, a comparison analysis was conducted. The current analytical comparison study demonstrates that lateral story displacement in buildings with blast loading is greater than that in buildings with seismic loads. Regular buildings perform better overall than L-shaped and C-shaped buildings in RC and composite structures when subjected to seismic load.

Nitish, Mayur, et al. [6] used CSI ETABS 2016 in this paper to create and analyze three-dimensional analytical models of G+20 storey buildings. Buildings in India's earthquake zone III are taken into account during the analysis. A G+20 story building with a flat slab (with drops) and traditional slab system is the subject of the analysis and design. Different parameters, such as story drift, displacement, stiffness, and time period, are compared. According to the study, story drift is 10% higher in conventional slabs than in flat slabs, and story displacements are found to increase linearly with building height and are 10% higher in conventional slabs than in flat slabs. Also, the time period in conventional slab building model structure is 1.05 times more than the flat slab building mode.

Shital, Kuldeep, et al. [7] studied the seismic behaviour of different types of slab structures i.e., Flat slab structure, conventional slab structure, flat slab structure with drop under different earthquake zones is done. It is a G+5 storey building analysed in ETABS software considering four zones II, III, IV, V. From the above analysis, the author concluded that story displacement is maximum in flat system and least in conventional slab system in all the seismic zones for both regular and irregular structure. Also, story shear is maximum in flat slab system and least in flat slab with drop system in all the seismic zone for both regular and irregular structure.

Sagar, Milind, et al. [8] analyzed a G+12 multistoried building having flat slab with column head and conventional slab using E-TABS software in this paper. The parameters like storey displacement, storey drift, storey shear, base shear and time period are compared. The zones considered were II, III, IV, V and the effect of height of building on performance of these types of buildings under seismic forces was studied. It shows that the joint displacements and base reactions of both buildings increases with respect to Zone II to Zone V. For maximum joint displacement traditional design performed better than flat slab building. When compared for base moment flat slab building performed better than traditional slab building.

Khaja Ateequddin, waseemsohail [9] dealt with the analysis of irregular flat slab multistorey building under lateral loads like seismic, wind loads. And to evaluate seismic conditions of a building like lateral displacement, storey drift, base shear, time period. In this paper, 7 models of a 10-storey building have been prepared by using ETABS software. Structural irregularities considered are building with a regular plan, re-entrant corners, re-entrant corners with L-shape, vertical irregularity on one side, vertical irregularity on both sides, rectangle shape with diaphragm discontinuity, inverse-T as diaphragm irregularity. Following a comparison of all 7 models, it is found that when the building's width is greater in one direction than it is in the other, the lateral displacement is reduced by 58 percent. Additionally, compared to Y direction, the storey drift in X direction is reduced. The model with vertical irregularity on both sides occurs at mode 3 for the shortest time duration. And for the model with the re-entrant corner L-shape, the longest time period occurs in mode 1.

Atif, M., et al. [10] completely assessed two slab systems in order to evaluate the seismic response to each slab system. The OMRF frame with shear walls and 4, 6, 8 storeys were adopted in this study. ETABS software was used for analysis and design, and the equivalent static technique, response spectrum, and time history were used for analysis. Storey drift, base shear, time period, storey shear, and axial force in columns are the criteria for evaluation. It shows that grid slab building has a better seismic response than ribbed slab building. Also, In OMRF building shear wall takes the immense percentage of the base shear and the storey shear. Approximately above 95% from the load would be withstood by shear walls. The author also concluded that the appropriate selection of the slab system plays an important role in the structure stability against the both of lateral and gravity forces.

Sreelaya P. P., Anuragi P. [11] compared the behavior of multistory buildings with flat slabs, ribbed slabs, and conventional grid slabs on ground and sloping ground. In the study a 3D analytical model with the slope chosen in between 0 to 20 degree is taken. Using the ETABS 2016 program, the response spectrum analysis is carried out for all models in accordance with IS 1893-2002. From the response spectrum analysis, the author studied the properties of the building such as displacement, storey drift and storey shear for all the models. The storey displacement for flat slab model is 50% more when compared with ribbed slab. It also states that the storey shear Grid slab model is 18.62% more when compared with the Flat slab model and 28.21% more when compared with ribbed slab. Plain ground has more storey drift than sloping ground; this is because the structure has more fixity. The author has concluded that conventional slabs are more suitable for construction in seismic zones when compared to flat slab or ribbed slab system.

Dr Ramakrishna Hegde, Chethana, Nanditha Vinod Kumar [12] studied and compared the procedure and performances of the Conventional RC frame slab, Flat Slab and Grid slab. Under earthquake zone II, these are researched and investigated. E-Tabs 2015 IS Code 456-2000 is used for the modes. Buildings with G+14 floors are considered, designed, and analysed for lateral (earth quake and wind) and gravity (DL and LL) load cases. According to the Indian Standard Code for earthquake resistant structures, the equivalent static method is applied to design and analyze the structures. It has been found that grid slab structures performed better seismically than flat slab structures. According to the author, grid and flat slabs have a 10% lower Storey drift than conventional slabs. The base shear of a conventional slab is 37% higher than a grid slab and 44% higher than a flat slab. Additionally, the conventional slab's storey displacement is 3% higher than that of the flat slat and grid slabs.

Vishesh P. Thakkar, Anuj K. Chandiwala [13] analyzed a G+5, G+8 and G+11 multistoried building having flat slab with drop, flat slab without drop and conventional slab using ETABS software. The factors taken into account included time, base shear, storey displacement, storey drift, and storey shear. The main objective of this paper is to compare the seismic behaviour of multi storey buildings having conventional RC frame, flat slab with drop and flat slab without drop in seismic zone III with type II soil. The effectiveness of these sorts of buildings against seismic stresses was studied in relation to building height. It was found that the storey displacement value of flat slab without drop building is about 44.11 % higher compared to conventional RC Frame building and 26.19 % higher compared to flat slab with drop building. Also, the storey drift of flat slab without drop building is about 42.56 % higher compared to conventional RC Frame building and 25.12 % higher compared to flat slab with drop building. Comparing flat slab buildings with drops to standard RC frame buildings, the base shear of flat slab buildings with drops is around 10.37 % greater and 1.24 % higher, respectively. Considering all the parameters, author concluded that conventional building has superior performance in earthquake against flat slab with drop and flat slab without drop.

V. Mani Deep, P. Polu Raju [14] used SAP2000 to do non-linear static analysis (pushover analysis) to comprehend the behavior of a G+9 multistory residential building in India's seismic zones II, III, IV, and V that has identical geometrical attributes. Investigations into the force-displacement relationships, inelastic structural behavior, sequential hinge formations, and other aspects of multistory building behavior have been conducted. According to the analysis's findings, base shear, displacement, and time period gradually increased as the seismic activity's intensity went from zone II to zone V. Additionally, a building with several zones has had a hinge formation obtained and seen. Plastic hinges were initially formed at the ends of beams and at the base of lower storey columns. From there, the formation of hinges spread to the middle and upper storeys. The author further determined that the extent of the building's damage is minimal and that, given the significance of the structure, columns at the lower story need to be repaired.

Rasna, Safvana, et al. [15] used a software-assisted direct approach for the manual design of a flat slab. Lack of a beam makes flat slabs more susceptible to punching shear. ETABS software has been used to analyze flat and conventional slab structures. The flat slab's maximum displacement value is lower at the middle of the strip. Additionally, the flat slab's value of shell stresses is lower than that of a traditional construction. Software analysis was used to compare the punching shear value of a flat slab to manual design. To prevent punching shear failure the strong concrete should be used, design the reinforcement correctly that is reinforce each possible failure plane, deepen the slab, making the column larger, introducing drop panels or flared column heads.

Renuka, Vinayak [16] analysed the structures having conventional slab and flat slab under the earthquake loading using ETABS version 13.1.2. Comparative analysis of conventional slab, flat slab without drop, flat slab with drop, flat slab with column head and flat slab with both drop and column head is done. 5 (G+4) storey, 10(G+9) storey, 15(G+14) storey buildings were modelled. The same buildings were studied for different seismic zone which are zone II, zone III, zone IV, and zone V and taking soil type II. Parameters like lateral displacement, storey drifts, storey shear, design base shear, and axial forces are studied. The author concluded that, flat slab without drop experiences more displacement than the flat slab with column head, with drop, both with drop and column head. As well as, for 5 storey, 10 storey and 15 storey building the displacement is increased as the height of the storey increases. It also states that both flat slab with drop and with column head experiences almost equal storey shear. And conventional slab experiences less drift compared to every other.

Anghan, Mitan, et al. [17] executed the complete modelling of 13 storey buildings, analysis, and design by the mean of SAP 2000 software. The performance of two buildings was studied in terms of lateral displacement, time period, base shear, story drift, in linear analysis by means of code-IS 1893 (part-1):2002. This paper shows that building in soft soil is more critical than building situated in medium and hard soil. Also, the column moments are more in conventional R.C. building compared to flat slab building. And axial force on column due to all load combination is approximately same in both building but shear force and bending moment is comparatively more in conventional slab building. Due to monolithic construction, conventional building has more time period than flat slab buildings. Future scope of work suggested is that the same study can be carried out by using steel structure.

Vinod Kumar Reddy, Vaishali [18] used ETABS software to conduct a comparative seismic analysis of conventional, flat slab with drop and without drop framed structures with and without masonry infill wall. The parameters studied are fundamental natural period, design base shear, displacements and story drift. It shows that the displacement of the flat slab with drop structures are having more deflection than conventional and flat slab with drop framed structures. Story drift is reduced by using masonry infill; however, story drift is greater in structures without masonry infill than in structures with masonry infill. 4 prepared models of structure without masonry infills, with considering equivalent diagonal strut, with considering shear wall and with considering bracing system are having displacements as Model 1 22 percent more than model 2, 38 percent more than model 3, and 25 percent more than model 4. The paper also concludes that conventional framed structures are having 7% more base shear than flat slab with drop framed structures and 16% more than flat slab without drop framed structures.

S.Mahesh , B. Panduranga Rao [19] performed analysis and design of a residential G+11 multi story building for earth quake and wind load using ETABS and STAAD PRO V8i. The research takes into account a variety of seismic zones, and for each zone, the behavior is evaluated using three different soil types—Hard, Medium, and Soft. It is concluded that when the regular and irregular configurations are compared, the base shear value is greater in the regular configuration. Because of the structure, the dimensions are more symmetrical. And the value of storey drift is greater in the regular configuration. Because of the more symmetrical dimensions of the structure. When comparing different zones, zone 5 has a higher base shear value for both regular and irregular configurations.

Fardis M.N. [20] dealt with the US codes and Eurocode 6,8, etc. This paper briefly shows modelling and analysis of buildings. Modelling process of beams and columns are learnt. There are special modelling aspects for walls which are also called as wide column analogy. Modelling of floor diaphragms consists of 2 ways, rigid and semi-rigid (flexible) diaphragm. Mostly floor diaphragms are modelled as rigid ones by introducing a master node at each floor close to the centre of mass of floor and not coinciding with anyone of the floor nodes. Only two translations in the diaphragm's plane and a rotation around its normal comprise this node's three degrees of freedom. All remaining nodes on that floor are called as slaves. Floor diaphragms are modelled as flexible only if floor itself or some of its beams are post-tensioned and it is necessary for a reliable calculation of the in-plane action effects due to post-tensioning. A general rule of thumb states that a footing can be considered rigid if it doesn't extend more than twice as far in plan from the vertical piece it supports. Also, a good measure of the regularity in plan (irrespective of the qualitative criteria for regularity) is the lack of significant rotation about the vertical (and of global reaction torque with respect to that axis) in the (few) lower most modes which helps in torsion check.

3. CONCLUSIONS

From the above study it is clear that researchers had studied different types of problems related to seismic analysis and design for different types of slabs. In addition, efforts were made to make the structure more economical by various changes in types of slabs, types of soils, masonry infills, slopes of grounds and many more. The softwares used to analyze and design were also different viz. E-TABS, Staad Pro, SAFE, SAP 2000. The seismic zone plays an important role in the construction of earthquake-resistant building structures. Base shear, displacement, and time period gradually increased as the seismic activity's intensity went from zone II to zone V (V. Mani Deep et al. 2017). Lack of a beam makes flat slabs more susceptible to punching shear. To prevent punching shear failure the strong concrete should be used, design the reinforcement correctly that is reinforce each possible failure plane, deepen the slab, making the column larger, introducing drop panels or flared column heads (Rasna P. et al. 2017). Nowadays, demand of multi-storeyed buildings is increased. The storey displacement is increased as the height of the storey increases (Renuka G. et al. 2016). It also states that both flat slab with drop and with column head experiences almost equal storey shear. Soil types are also critical in case of seismic analysis. Building in soft soil is more critical than building situated in medium and hard soil (Anghan Jaimis et al. 2016). Masonry infill wall in a building reduces the story drift of structure (M Vinod Kumar Reddy et al. 2014).

When the regular and irregular configurations are compared, the base shear and storey drift value is greater in the regular configuration as the dimensions are more symmetrical (S. Mahesh et al. 2014). Slope of ground always vary from place to place. Plain ground has more storey drift than sloping ground; this is because the structure has more fixity (Sreelaya P. P. et al. 2019). Structural irregularities like plan irregularity are an important factor in failure of building. Storey drift is highest in L shape building and least in rectangular building in equivalent static analysis and storey displacement is lowest in rectangle-shaped buildings with bracing and without bracing (Farheen S. S. et al. 2021). Also, regular buildings perform better overall than L-shaped and C-shaped buildings in RC and composite structures when subjected to seismic load (Sridevi et al.2021). When the building's width is greater in one direction than it is in the other, the lateral displacement is reduced by 58 percent; additionally, compared to Y direction, the storey drift in X direction is reduced in the given cases (Khaja Ateequddin et al.2019). Moreover, adding brick and shear walls to the models would reduce displacement (Bidreddy, R.S. et al. 2022). Story displacement is maximum in flat system and least in conventional slab system in all the seismic zones for both regular and irregular structure (Shital Borkar et al. 2021).

Structure with irregularities considering different types of slabs is a subject of concern as it is highly unstable and is in need of additional research. Different shapes of buildings have different effects in seismic analysis and that impact can be minimalised. Hence, plan irregularities and their combinations with different slabs can be a future scope of work.

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