Comparison of seismic performance of various slab types in a symmetrical building plan using the Response spectrum method

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***Abstract*- This study compares seismic performance of various types of slabs –conventional slab, flat slab & grid slab in a symmetrical building plan for all zones using the method response spectrum by using the software ETABS.G+10 Floor building is modeled with an equal column sizes and analyzed for all 4 seismic zones. Analysis shows maximum storey displacement & maximum storey drift of flat slab is higher value. Storey shear of conventional slab showing higher value.storey stiffness of grid slab is showing higher value.**

***Index Terms*- Flat slab, conventional slab, grid slab, storey shear, storey stiffness, storey displacement, storey drift.**

I. INTRODUCTION

With a vast workforce and abundant natural resources, India is emerging as one of the fastest-growing countries. Quickest growing cities like Mangalore, Bangalore, and Delhi face a scarcity of land space, necessitating the construction of high-rise buildings. The use of reinforced concrete material for the development of high-rise structures is widespread globally. The slab, a crucial horizontal structural component in every R.C building, plays a pivotal role in accepting loads and transferring them to beams, columns, and ultimately to the ground.

II. AIM AND OBJECTIVE OF WORK

Aim

1. The lateral behavior of a building designed in accordance with I.S.1893 is assessed using the equivalent static method for study and comparison.
2. To adopt suitable slab system for the structure in the relevant earthquake zone.

Objective

1. Study the response of various types of slabs under earthquake loads.
2. Analyze the behavior of various types of slabs in different earthquake zones.
3. To find suitable type of slab in particular earthquake zone.

III. LITERATURE REVIEW

Sandesh D. Bothara., et.al [1] the study compared seismic performance of Flat Slab and Grid Slab systems in a 9-story building. Response Spectrum analysis revealed differences in storey drift, shear force, and bending moment. Flat slabs benefited from shear-enhancing drops, while grid slabs showed lower drift except for the first four stories.

R.S. More, V.S. Sawant., et.al [2] Study evaluated storey drift in various flat slab configurations in reinforced concrete buildings subjected to minimum lateral forces. Findings revealed that flat plates exhibited the highest drift, exceeding that of flat slabs and grid slabs by 18% and 45%, respectively. Additionally, flat plates experienced 14% higher shear forces than grid slabs for all soil conditions.

Navyashree. [4] The study compared multi-storey industrial buildings with flat slabs to traditional RC frame structures .Findings showed that lateral displacement increased with height, with flat slabs exhibiting 28-57% greater displacement. The natural period also increased with height, being 14-33% longer for flat slab buildings. Furthermore, flat slab constructions experienced significantly higher storey drift (28-60%), necessitating consideration of additional moments in column design.

Thummala Spoorthy [17] this study utilizes ETABS software to compare seismic variations between conventional RC slabs and flat slabs with drops in a G+15 storey building across different zones. Findings reveal that flat slabs exhibit higher storey displacement (0.33% more), higher storey shear (25.3% more), and higher overturning moment (0.26% less) compared to conventional slabs. Overall, flat slabs, especially with appropriate design features, demonstrate greater flexibility and resilience under seismic conditions compared to conventional slabs.

Tejas B, Raghu M E [18] This study investigates the seismic behavior of a G+9 storey structure with a grid slab using ETABS software in varying seismic zones, particularly Zone IV. The research involves an extensive literature review, structural modeling, and analysis. Conclusions drawn from the study highlight that grid slabs in Zone IV exhibit lower storey displacement, and the modular scheme enhances overall building stiffness, reducing sway issues. Additionally, decreasing spacing between grid beams is shown to increase the building's load-carrying capacity and overall performance.

Abhijit K Sawwalakhe.,et.al [14] This study compares three scenarios (conventional, flat, and grid slabs) for a G+5 residential structure with various span sizes and a 4-meter floor-to-floor height. While considering different parameters and zone III analysis, it reveals that flat slabs, although heavier, offer architectural flexibility and cost effectiveness for high-rise buildings. Conventional slabs suit residential and small spans, while grid slabs are ideal for larger spans.

Deepak Kumar Vishwakarma.,et.al [15] G+14 storey building with different slab types and C-Type & L-Type shear walls. Six models with specific dimensions are analyzed using STAAD.PROV8i software, following IS code practices. The key findings include an increase in storey displacement, shear force, bending moment, column axial forces, base shear, and beam torsion when transitioning from Flat Slab to Conventional Slab or Grid Slab systems, with variations in X and Z directions for each parameter. Stresses also show increments in these transitions.

IV. METHODS OF EARTH QUAKE ANALYSIS

Earthquake analysis of a building can be done using following two methods

1. Equivalent static analysis
2. Dynamic analysis

Under dynamic analysis Response spectrum and Time history methods are carried out. In this study response spectrum method is used and results are compared. When a structure's foundation is struck by seismic forces, the ground motion can move with it. It demonstrates that most structure movement occurs above ground. The structure's movement in relation to the ground is rejected as a dynamic amplifier. It is dependent upon the inherent vibration frequency, dampening, kind of foundation, and structural detailing method. The maximum acceleration as a function of the structure for a certain damping ratio for earthquake excitation at the base for a single degree of freedom system is referred to as the spectral acceleration coefficient Sa/g, or the response design acceleration spectrum.

V. METHODOLOGY

For this study, a G+10 storey building with a 3.0-meters height for every story that is regular in plan and the building plan comprises of 5 bays in both x and y directions with 4m c/c spacing having 3 type of slab systems. Conventional slab, Flat slab & Grid slab systems are modelled. These structures were developed in conformity to the Indian Code of practice for seismic resistant construction of buildings. It is considered that the buildings are typical moment-resistant structures, with the floors functioning as inflexible diaphragms and fixed at the base. Building story heights are taken to be consistent with the ground floor. The ETAB software system is used to simulate the buildings. All necessary structural components, such as material properties, loads, load combinations, member sizes, response spectrums, etc., must be determined before analysis can begin. After the analysis is complete, we may extract data for comparing the performance of flat slab, grid slab, and conventional slab buildings, such as displacement, storey shear, bending moment, drift ratio, and axial forces for comparing the performance of flat slab, Grid slab and conventional slab building and results are represented in graph. Twelve models were studied for the behavior of flat slab, conventional beam slab and grid slab in several earthquake zones. Models are studied in zone-II, zone-III, zone-IV and Zone V comparing storey drift, storey shear and column and slab forces in several locations of the buildings.

Structure modeling

A G+10 residential building is modelled using E-TABS software. In the current study 3 models with 10 floors is analyzed for all 4 earthquake zones. Following table shows the building data considered for the study.

Table 1 Building Preliminary data

Properties	**Preliminary Data's**
Floors	G + 10
Floor height	3.0 m
Beam sizes	230x750mm (Floor beams) 230 x 450 (Plinth beam)
Column sizes	750 x 750mm (Base – 3rd floor) 600 x 600mm (4^{th}– 7^{th} floor) 450 x 450m (8^{th} –Terrace Floor)

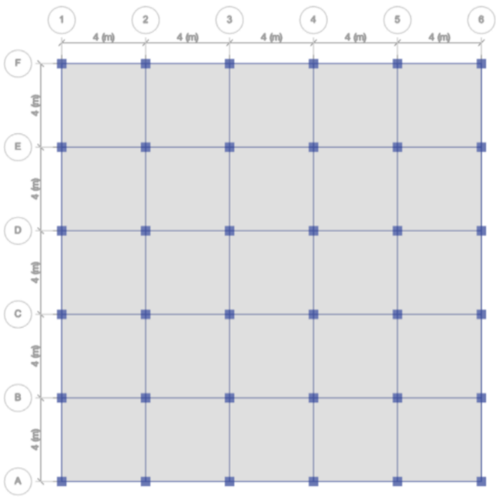
Thickness of wall	200 mm
Concrete grade	M 25
Steel grade	Fe 500
Earth quake zone	II, III, IV,V

Table 2 Dead load and Live load

Load types	**Loads**
Floor load	2.0 kN /m^2
Floor finishes	1.0 kN /m^2
Wall load	10.0 kN/m
Live load for terrace	1.5 kN/m^2

VI.ETABS MODELLING

1) Conventional slab model



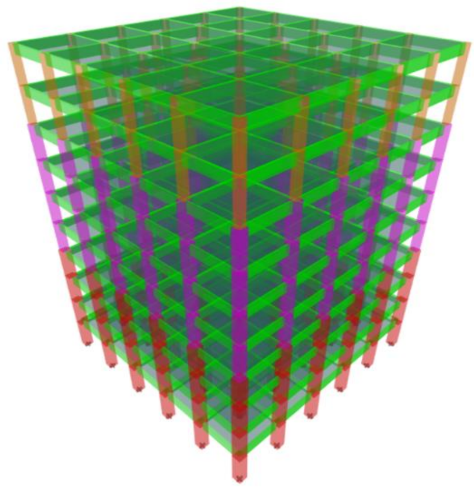
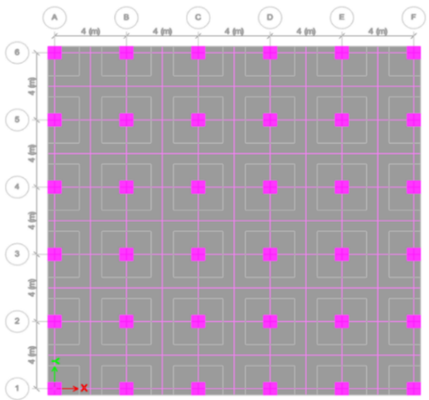


Fig -1: Model of a Conventional slab plan in ETABS. **Fig -2**: Conventional slab model in an isometric view.

2) Flat slab model



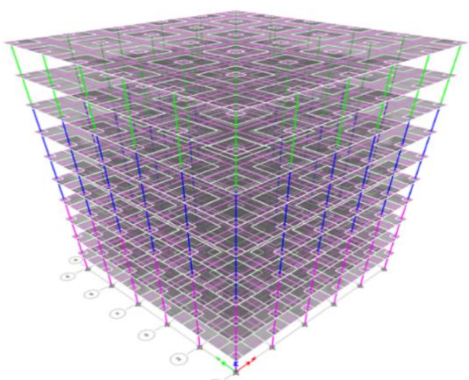


Fig -3: Model of a Flat slab plan in ETABS. **Fig -4**: Flat slab model in an isometric view

3) Grid slab model

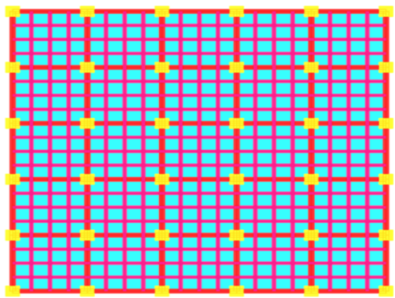


Fig -5: Model of a Grid slab in ETABS

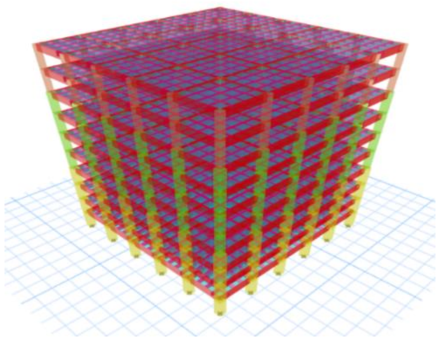


Fig -6: Grid slab model in an isometric view

VII.ETABS ANALYSIS RESULT

MAX STOREY DISPLACEMENT:

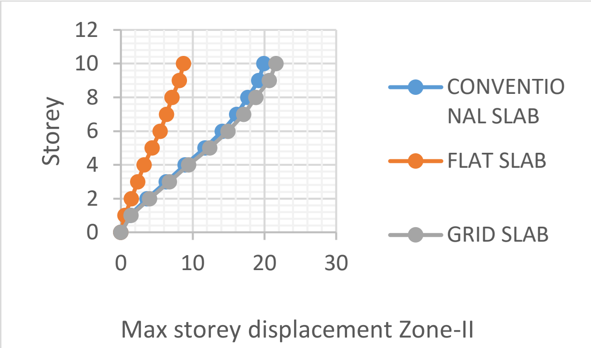


Chart -1: Max storey displacement - Zone II (RS X & RSY)

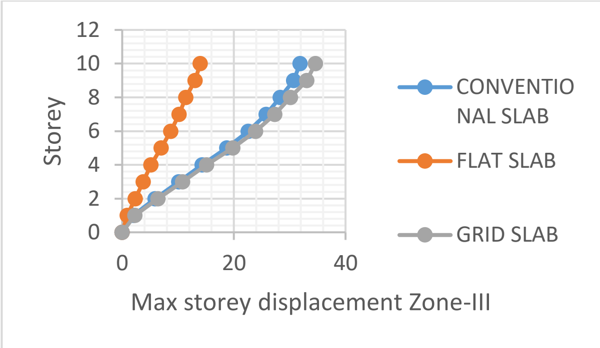


Chart -2: Max storey displacement - Zone III (RS X & RSY)

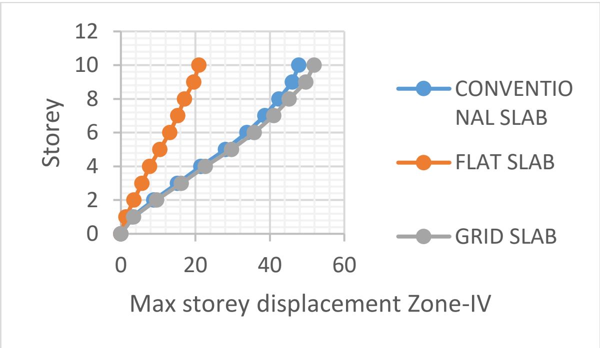


Chart -3: Max storey displacement - Zone IV (RS X & RSY)

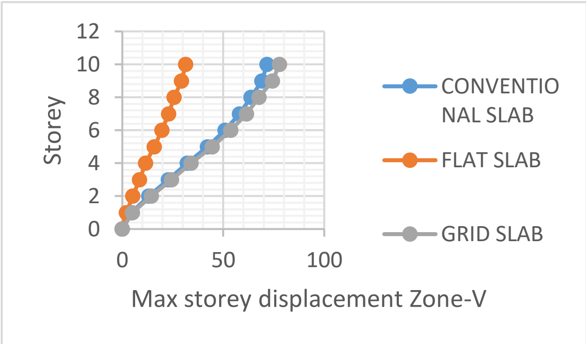


Chart -4: Max storey displacement - Zone V (RS X & RSY)

MAX STOREY DRIFT:

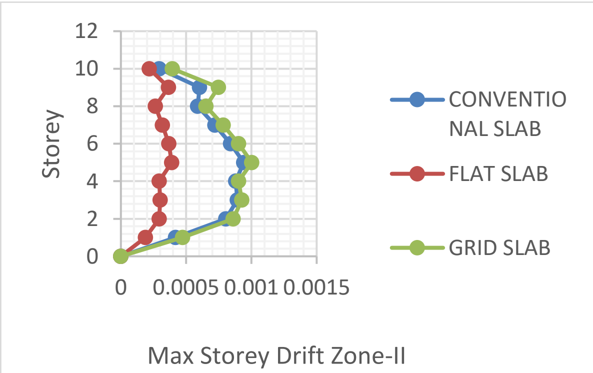


Chart -5: Max storey drift - Zone II (RS X & RSY)

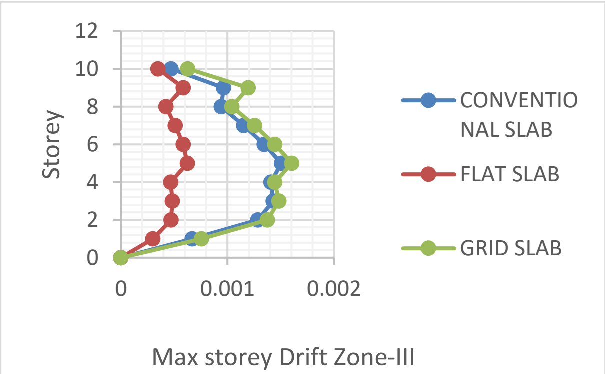


Chart -6: Max storey drift - Zone III (RS X & RSY)

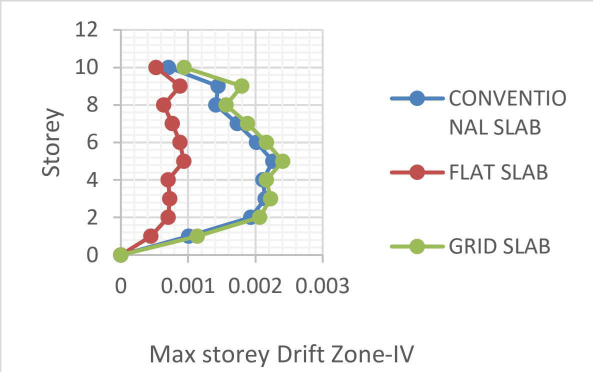


Chart -7: Max storey drift - Zone IV (RS X & RSY)

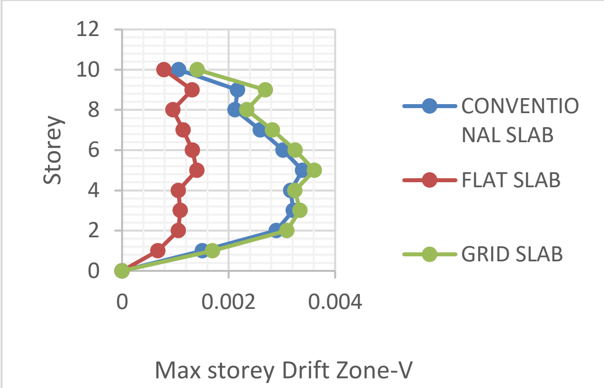


Chart -8: Max storey drift - Zone V (RS X & RSY)

MAX STOREY SHEAR:

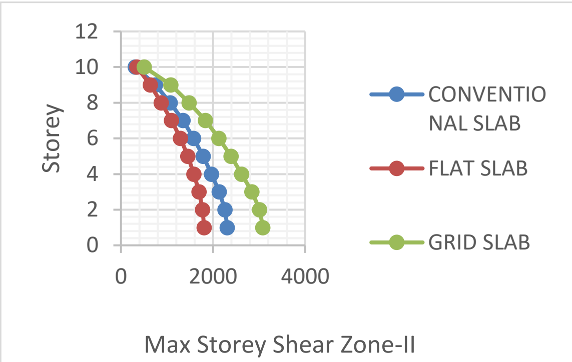


Chart -9: Max storey shear - Zone II (RS X & RSY)

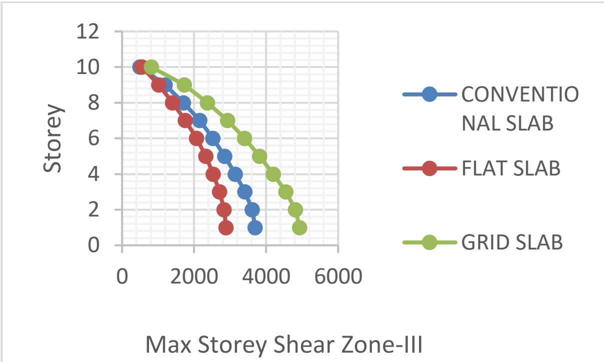


Chart -10: Max storey shear - Zone III (RS X & RSY)

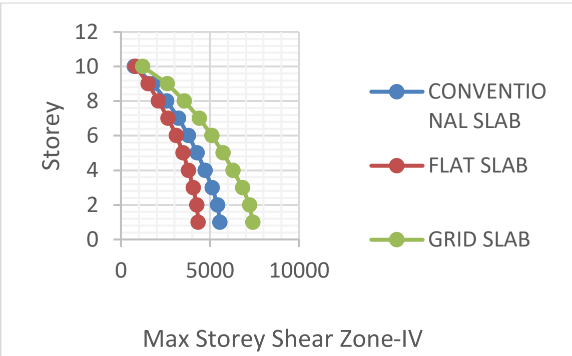


Chart -11: Max storey shear - Zone IV (RS X & RSY)

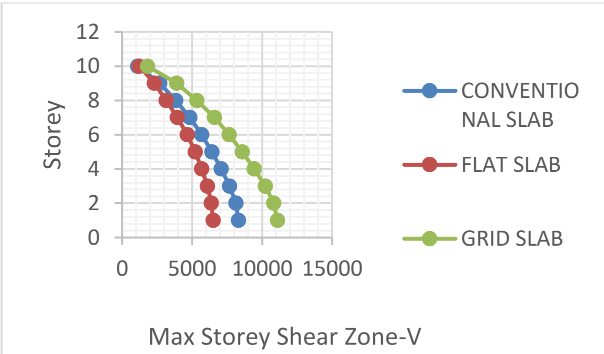


Chart -12: Max storey shear - Zone V (RS X & RSY)

MAX STOREY STIFFNESS:

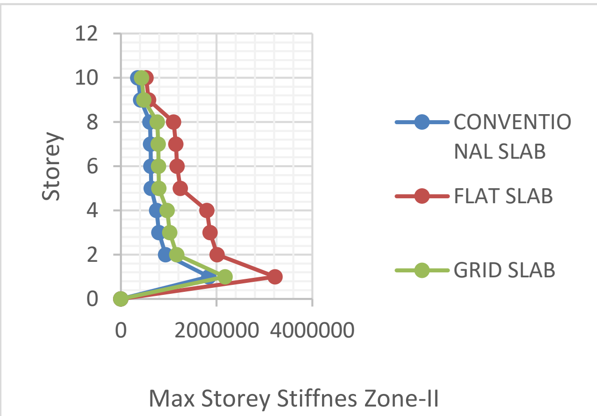


Chart -13: Max storey stiffness- Zone II (RS X & RSY)

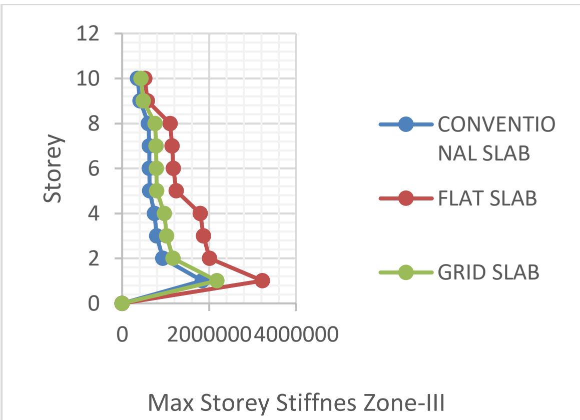


Chart -14: Max storey stiffness - Zone III (RS X & RSY)

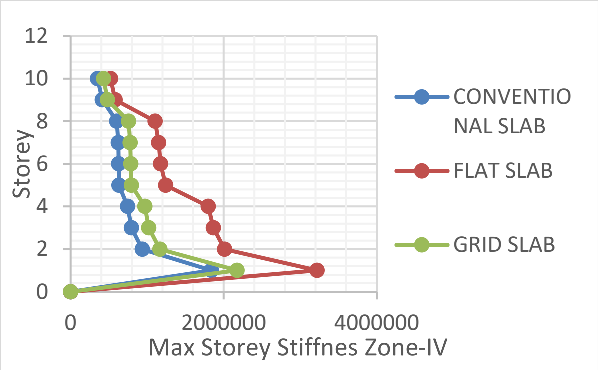


Chart -15: Max storey stiffness- Zone IV (RS X & RSY)

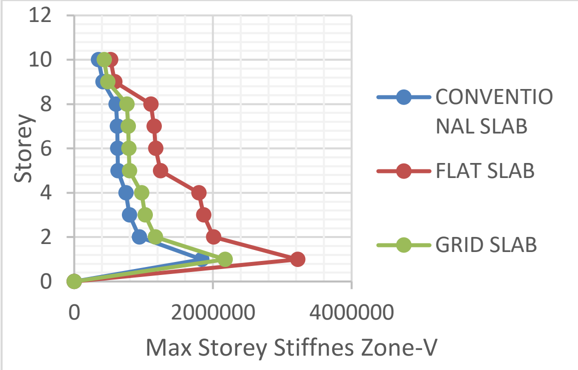


Chart -16: Max storey stiffness – Zone V (RS X & RSY)

VIII. CONCLUSION

After conducting earthquake analysis on distinct slab systems, the following key findings emerge:

1. For a multi-story building with grid slab, the highest concrete requirement is observed, while the flat slab requires the least for the same span/grid size. Conversely, the conventional slab system demands more concrete than the flat slab for multi-story buildings.
2. Regarding maximum storey displacement, the flat slab exhibits a higher value compared to both conventional and grid slabs.
3. When analyzing maximum storey drift, the flat slab displays a higher value than both conventional and grid slabs.
4. In terms of storey shear, the conventional slab demonstrates a higher value compared to grid and flat slabs.
5. For storey stiffness, the grid slab showcases a higher value compared to both conventional and flat slabs, based on the earthquake analysis results.

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