RESEARCH ARTICLE OPEN ACCESS

Comparative Study of Seismic Behavior of Reinforced Concrete Building with Flat Slab and Conventional Slab Floor System

Nyome Tin [1], Khin Thanda Htun [2]
Department of Civil Engineering
West Yangon Technological University
Union of Myanmar

ABSTRACT

Nowadays, the need of high rise structure building with flat-slab is increasing over traditional RC frame building because of flexibility in construction, the free design of space, architectural function and reduction in construction time. Because of the shear walls, flat-slab structural building is significantly more flexible for lateral loads than conventional beam column building and that make the building deforms significant and more vulnerable under seismic events. This paper is assessing of seismic behavior of RC structure with flat slab and conventional slab on a full scale 16 storey representative of high rise building in different seismic regions. The analysis is done by using ETABS software performed based on Uniform Building Code 1997 (UBC 97) for environmental loading and, American Concrete Institute (ACI 318-99) for consideration of design requirements for structural elements. Linear dynamic response spectrum analysis will be used on the structure. The seismic behavior such as storey displacement, storey drift, storey shear for conventional RC frame and pure flat slab have been studied and analysis results are being compared in the different seismic zones.

Keywords :— Conventional RC frame, Flat slab, Seismic, ETABS, Response spectrum analysis.

I. INTRODUCTION

Earthquakes result from the sudden movement of tectonic plates in the earth's crust. The movement takes place at fault lines, and the energy released is transmitted through the earth in the form of waves that cause ground motion many miles from the epicentre. Regions adjacent to active fault lines are the most prone to experience earthquakes. The seismic zone map of Myanmar is based on historical records and takes into account the expected frequency and intensity of earthquakes seismic zones 1 through 4 represent progressively higher severities of expected seismic intensity. Earthquakes consist of random horizontal and vertical movement of the earth's surface. Seismic design has emphasized the effects of horizontal ground motion, because the horizontal components and because structures are usually much stiffer and stronger in response to vertical loads than they are in response to horizontal loads [3].

Concrete is the most widely used construction material in the world compare to steel as concrete is well known as the most versatile and durable construction materials. Concrete slab floor is one of the key structural elements of any building. Concrete floor choice and can have a surprisingly influential role in the performance of the final structure of the building, and importantly will also influence people using the building. The beam supporting the slabs can generally be wide and flat or narrow and deep beam, depending on the structures requirements. Beams supporting the slab in one or two way spanning slabs tend to span between columns or wall and can be simply supported or continuous in this beam-slabs system, it is quite easy to visualize the path from the local point to column as being transferred from slab to beam to column, and from this visualization then to compute realistic moments and shears for design of all members [5].

Flat slab is also referred to as beamless slab or flat plates. The slab systems are a subset of two-way slab family, meaning that the system transfer the load path and deforms in two directions. It is extremely simple structure in concept and construction, consisting of a slab of uniform thickness supported directly by the columns with no intermediate beams. The choice of flat slab as building floor system is usually a matter of magnitude of the design loading and of the spans. The capacity of flat slab is usually restricted by the strength in punching shear at the sections around columns. Generally, column capitals and drop panels will be used within the flat slab systems to avoid shear at the column section when larger loads and span are present. Flat slab is highly versatile element widely used in construction due to its capability of providing minimum depth, faster construction and allowing a flexible column grid system [5].

II. PROBLEM STATEMENT OF STUDY

In present work in order to determine dynamic response of flat slab with perimeter beam building and conventional slab in RC building in different seismic zones, it will be modelled and analyse in ETABS software. Linear dynamic response spectrum analysis will be performed on the structures. In this paper, twenty-six design load combinations are used for superstructure of both buildings. Load combinations are based on UBC-97 and the design of members are carried out by using ACI 318-99. The size, material properties and loads of study structures are as follows.

A. Type, Size, Location and Height of Structure

- 16-storeyed RC building with conventional slab and flat slab with perimeter beam
- Maximum dimension - 110 ft x 110 ft
- Location -Zone 2B and 4 (Intermediate and high seismic zones)
- Ground floor height - 12 ft
- Typical floor height - 10 ft

B. Material Properties

For selected models,

Material properties used for selected structure are:

(i) Design Property Data

- Concrete compressive strength,(f'_c) = 4 ksi
- Yield strength of steel(f'_y) = 50 ksi
- Yield strength of tendon(f'_y) = 245.1 ksi

(ii) Analysis Property Data

- Modulus of Elasticity(concrete) = 3122 ksi
- Modulus of Elasticity(steel) =29000 ksi
- Modulus of Elasticity (tendon) =28500 ksi
- Weight per unit volume(concrete) = 150 pcf
- Weight per unit volume (Rebar & tendon) =490 pcf
- Poisson's ratio(concrete) = 0.2
- Poisson's ratio(steel) = 0.3
- Coefficient of Thermal Expansion = $5.5\text{x}10^6$

C. Loading Considerations

Super imposed dead loads,

- Dead load for Floor = 20 psf
- Dead load for Roof = 20 psf
- Dead load for Stair = 20 psf
- Weight of elevator = 3 ton
- Weight of 4-1/2 inch brick wall = 50 psf
- Weight of 9 inch brick wall = 110 psf
- Dead load for brick wall(Flat slab) = 50 psf

Live loads,

- Live load for Floor = 40 psf
- Live load for Roof = 20 psf
- Live load for Stair = 100 psf

Wind loads,

- Wind velocity = 120 mph
- Exposure type = C
- Windward coefficient = 0.8
- Leeward coefficient = 0.5
- Important factor = 1

Earthquake loads,

- Seismic zone = 2B & 4
- Zone factor = 0.2 & 0.4
- Soil type = SD
- Response modification factor = 5.5 & 8.5
- Seismic coefficient, C_a = 0.28 & 0.66
- Seismic coefficient, C_v = 0.4 & 1.28
- Building period coefficient, C_t = 0.02
- Important factor = 1

D. View of building

Ground floor, typical floor plan and 3D view of 16-storeyed RC buildings with flat slab and conventional slab.

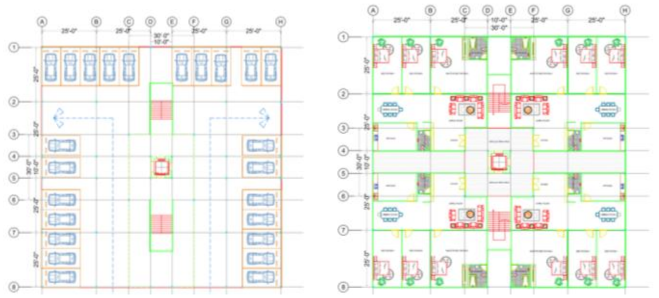

Fig 1 Ground floor and typical floor plan of selected building

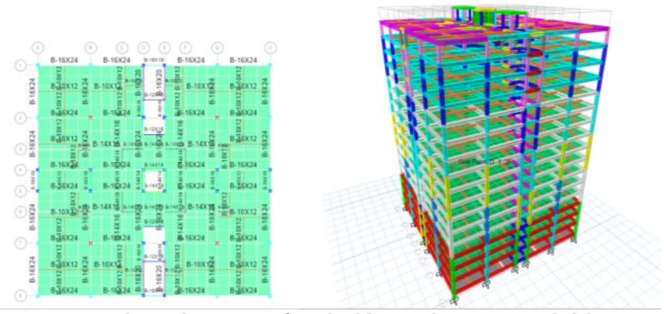

Fig 2 Plan and 3D view of RC building with conventional slab

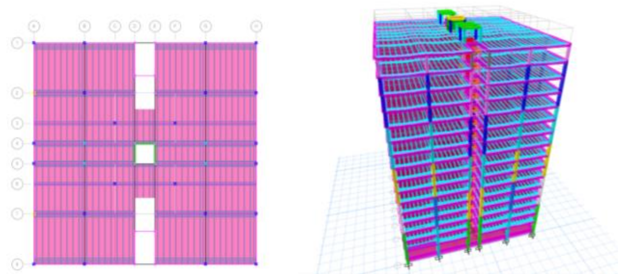

Fig 3 Plan and 3D view of RC building with conventional slab

E. Determination of load combination

Design codes applied are ACI 318-99 and UBC 97. Design load combinations for RC building with flat slab and conventional slab are as follow.

TABLE I
LOAD COMBINATIONS

No	Conventional Slab	Flat Slab
1	1.4 D	1.4D + PT
2	1.4 D + 1.7 L	1.2D + 1.6L + PT
3	1.05D + 1.275L + 1.275WX	1.2D + L + WX + PT
4	1.05D + 1.275L - 1.275WX	1.2D + L - WX + PT
5	1.05D + 1.275L + 1.275WY	1.2D + L + WY + PT
6	1.05D + 1.275L - 1.275WY	1.2D + L - WY + PT
7	0.9D + 1.3 WX	0.9D + WX + PT
8	0.9D - 1.3 WX	0.9D - WX + PT
9	0.9D + 1.3 WY	0.9D + WY + PT
10	0.9D - 1.3 WY	0.9D - WY + PT
11	0.9D + 1.02EQX	0.9D + EQX + PT
12	0.9D - 1.02EQX	0.9D – EQX + PT
13	0.9D + 1.02EQY	0.9D + EQY + PT
14	0.9D - 1.02EQY	0.9D - EQY + PT

15	0.79D + 1.02EQX	1.2D + L+ EQX + PT
No	**Conventional Slab**	**Flat Slab**
16	0.79D - 1.02EQX	1.2D + L - EQX + PT
17	0.79D + 1.02EQY	1.2D + L + EQY+ PT
18	0.79D - 1.02EQY	1.2D + L - EQY + PT
19	1.16D + 1.28L + EQX	1.2D + L + SPEC1+PT
20	1.16D + 1.28L - EQX	1.2D + L - SPEC1+PT
21	1.16D + 1.28L + EQY	1.2D + L + SPEC2+PT
22	1.16D + 1.28L - EQY	1.2D + L – SPEC2+PT
23	1.05D + 1.28L + EQX	0.9D + SPEC1+PT
24	1.05D + 1.28L - EQX	0.9D - SPEC1+PT
25	1.05D + 1.28L + EQY	0.9D + SPEC2+PT
26	1.05D + 1.28L - EQY	0.9D - SPEC2+PT

Where,

D = Dead load
L = Live load
WX = Wind load in X direction
WY = Wind load in Y direction
EQX = Earthquake load in X direction
EQY = Earthquake load in Y direction
SPEC1 = Dynamic load in X direction
SPEC2 = Dynamic load in Y direction
PT = Post tension load

III. RESULT AND DISCUSSION

Dynamic analysis for RC building with conventional slab and flat slab with perimeter beam was done by using response spectrum analysis for earthquake zone 2B and 4 per UBC 97. There is noteworthy change in seismic parameters like storey displacement, storey drift, storey shear, time period and base shear is noticed and thrashed out below.

A. Storey Displacement

Storey displacement is considered as one the important factors when structures are subjected to lateral loads like earthquake and wind loads. As per study analysis, storey displacement of flat slab is more vulnerable than conventional slab. From figure 4 and 5, it was observed that the storey displacement of flat slab with perimeter beam is 30.93% and 26.91% higher than conventional slab in RC building for intermediate and high seismic zones.

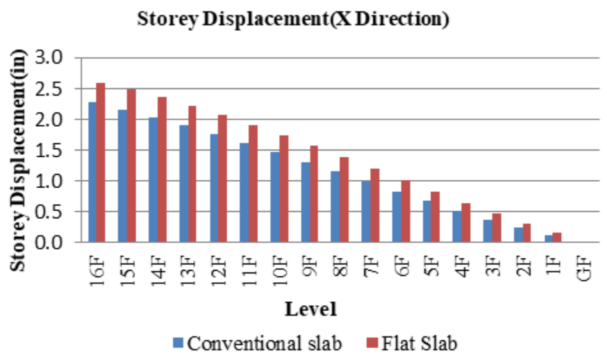

Fig 4 Storey Number vs Storey Displacement in X Direction for intermediate seismic zone

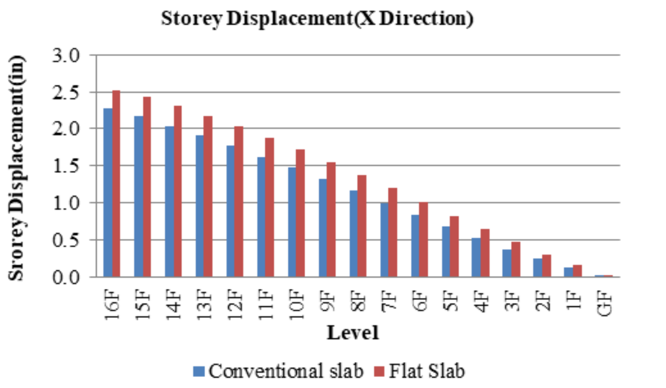

Fig 5 Storey Number vs Storey Displacement in X Direction for high seismic zone

B. Storey Drift

Storey drift is defined as difference between lateral displacements of one floor relative to other floor. Total storey drift is absolute displacement of any point relative to the base [4]. Storey drift limits may be exceeded when it is demonstrated that greater drift can be tolerated by both structural elements and non-structural elements that could affect life safety. The drift used in this assessment shall be based upon the Maximum Inelastic Response Displacement, Δ_M. Calculated storey drift using Δ_M shall not exceed 0.025 times the storey height for structures having a fundamental period of less than 0.7 second. For structures having a fundamental period of 0.7 second or greater, the calculate storey drift shall not exceed 0.02 times the storey height [1]. As per field of research, storey drift of flat slab is more assailable than conventional slab in RC building. From figure 6 and 7, it was noted that the flat slab with perimeter beam is 41.29% and 28.00% higher than conventional slab in RC building for intermediate and high seismic zones.

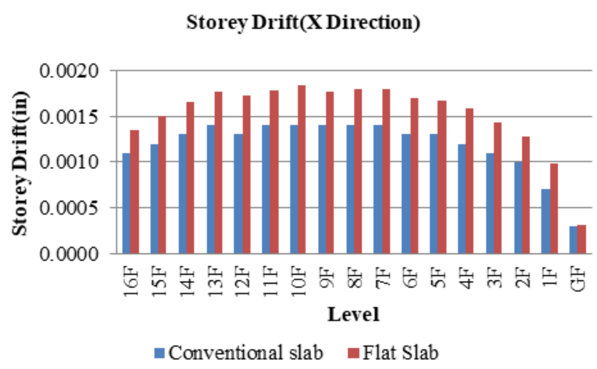

Fig 6 Storey Number vs Storey Drift in X Direction for intermediate seismic zone

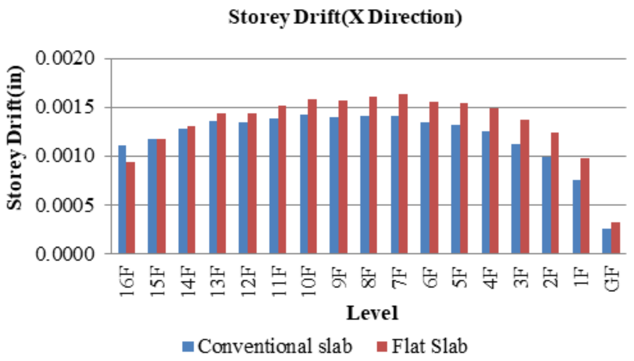

Fig 7 Storey Number vs Storey Drift in X Direction for high seismic zone

C. Storey Shear and Base Shear

Seismic forces are lateral loads (external forces) which intern will create total relative forces at column base in direction opposite to that of lateral load i.e.(sum of lateral load = base shear) this overall reactive forces is base shear. The storey shear is the maximum at ground level and keeps on decreasing towards the top storey of structure [4]. From figure 8 and 9, it was stated that the storey shear in flat slab is 49.62% and 49.58% higher than conventional slab in RC building for intermediate and high seismic zones.

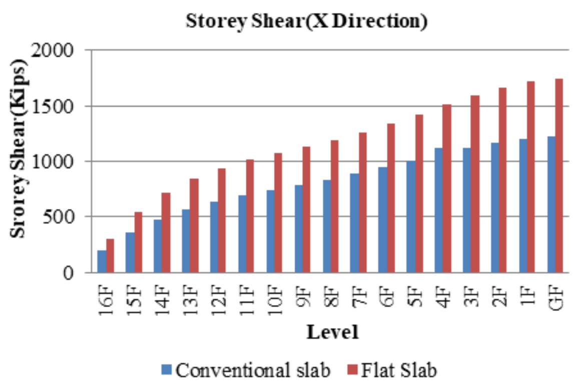

Fig 8 Storey Number vs Storey Shear in X direction for intermediate seismic zone

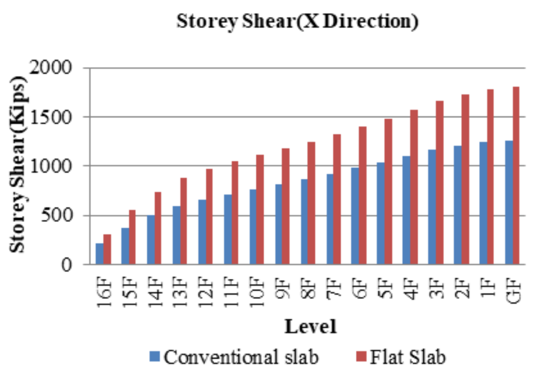

Fig 9 Storey Number vs Storey Shear in X direction for high seismic zone

D. Time Period

Time required for the un-damped system to complete one cycle of free vibration is the natural time period of vibration of system in unit of second. These are 18 number of mode in building: each mode has different value of time period. Time period depends on mass of building and it indicates flexibility of building. The number of mode increase, the value of time period decrease [4].From figure 10 and 11, it was observed that the time period in flab with perimeter beam is 30.77% and 35.00% longer compared to conventional slab in RC building for intermediate and high seismic zones.

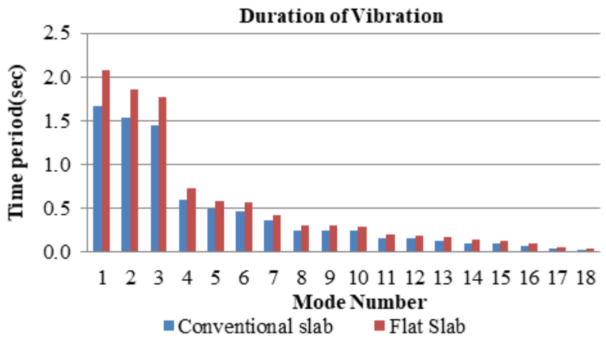

Fig 10 Mode Numbers vs Time Period for intermediate seismic zone

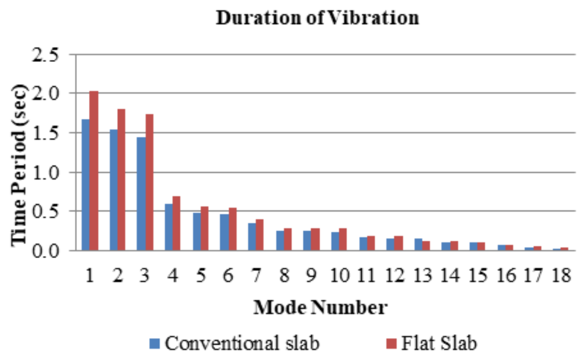

Fig 11 Mode Numbers vs Time Period for high seismic zone

IV. CONCLUSIONS

This is the summary of paper for conventional RC framed building and flab slab with perimeter beam building under different seismic zones with type IV stiff clay soil. From the above figures, the following conclusions have been described.

- ❖ Storey displacement is high at first floor and least at the top of the structures. The storey displacement of flat slab with perimeter beam building is 30.93% and 26.91% higher than conventional RC framed building for intermediate and high seismic zones. But storey displacement in intermediate zone is more than in high seismic zone because of different columns sizes.

- Storey drift is high at first floor and least at the top of the structures. Storey drift in flab slab with perimeter beam building is 41.29% and 28.00% higher compared to conventional RC framed building for intermediate and high seismic zones.
- The base shear is the maximum at ground floor and keeps on decreasing towards the top of the structures. The base shear in flab slab with perimeter beam building is 49.62% and 49.58% higher than conventional RC framed building for intermediate and high seismic zones.
- The time period is the maximum at mode 1, 2 and 3.After mode 3 time period reduces drastically. The time period of building with flat slab with perimeter beam is 30.77% and 35.00% longer compared to conventional RC framed building for intermediate and high seismic zone. As the result, period of vibration in high seismic zone is longer than in intermediate zone.
- By comparing all above parameters it was found that conventional building has superior performance in earthquake against flab slab with perimeter beam building.

V. FUTURE SCOPE OF STUDY

1. The structure can be analyzed with different soil types.
2. Cost and construction time comparison of conventional RC framed building and flat slab building under different seismic zones.
3. Nonlinear pushover analysis of flat slab building can be performed using ETABS instead of linear response spectrum analysis.
4. Comparative study of pretension and post tension of flat slab with and without drop.

ACKNOWLEDGMENT

First of all, the author would like to express her gratitude to Dr. Khin Latt, Professor and Head, Civil Engineering Department, West Yangon Technological University, for her constructive comments, and true-line guidance. The author also wishes to thank to Dr. Khin Thanda Htun, Professor, Civil Engineering Department, West Yangon Technological University, for enthusiastic and encouragement during a long period of this study.

The author especially wishes to acknowledge her teachers of Civil Engineering, West Yangon Technological University.

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