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Analysis of PT flat slab with Drop- Considering Seismic Effect

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Abstract - *As we know that in the present scenario buildings with post-tensioned flat slab are gaining more popularity than conventional RCC buildings for flooring system due to its increased number of floors and even due to its capability to the resistance during earthquake. In this paper a plan of residential building with post-tensioned flat slab with drop considering seismic effect is considered for the analysis using CSI SAFE 2016 software. A floor system of post-tensioned flat slab with drop model is considered for the analysis. The modeling and analysis is done using CSI SAFE 2016 software. An attempt is made to study the parameters such as moments, stresses, time period, frequency and behavior of flat slab under seismic effect for Equivalent Frame method and strip base method.*

Key Words: PT flat slab with drop, Equivalent Frame method, Strip base method, Stresses, Moments, Shear forces, Frequency, Time period.

1. INTRODUCTION

Post tensioning system is probably the latest discovery in man's continuing search for new construction materials and methods. The concept of pre-stressing is employed to express the mechanism of introducing internal stresses(forces) within a concrete or masonry element during construction procedure in order to counteract the external loads applied when the structure is allowed to use (known as service loads). The internal stresses are practically activated by tensioning high-strength steel, and are done before or after concrete placed. When the steel is tensioned prior to the concrete placement, the mechanism is called pre-tensioning. The time when the steel is tensioned posterior to the concrete placement, the mechanism is called post-tensioning. For the reason that pre-tensioning requires personally planned casting beds, it is second hand by and large in the precast manufacturing administer to manufacture clear-cut shapes that be able to be transported to a work site. Post-tensioning is finished onsite by introducing post-tensioning tendons inside the definite form work in a conduct comparable to introducing rebar.

The floor plan of residential building has been chosen to analyze using SAFE 2016 software for thesis work of post tensioned flat slab with drop considering seismic effect.

1.1 Objectives of the Present Work

- Analysis of the PT flat slab with drop in CSI SAFE 2016 software.
- To determine stresses, moments, forces of the pt flat slab.
- To evaluate the frequency and time period of the structure.
- Equivalent frame analysis of PT slab with drop.

1.2 Material Properties and Loads

This work has been analysed using CSI SAFE 2016 software. For the analysis the parameters considered are given below:

Grade of concrete: M30
Grade of steel: Fe400
Modulus of elasticity of steel, E_s: $2x10^5$N/mm^2
Ultimate stress of tendons, f_u: 1860 N/mm^2
Live load: 2kN/mm^2
Super imposed dead load: 1kN/mm^2
Slab thickness: 150mm
Drop thickness: 250mm
Storey height: 3m
Drop panel size at corners: 1200mm x 1200mm
Drop panel size in remaining parts: 1050mm x 1050mm
Size of columns at corners: 600mm x 600mm
Remaining size of columns: 450mm x 450mm

1.3 Model Description

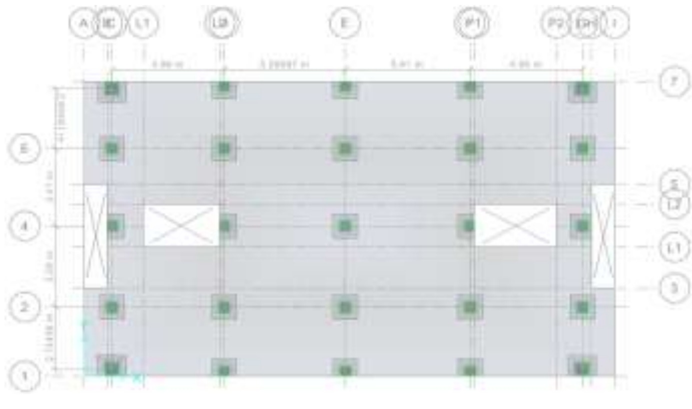


Fig- 1: Typical Floor plan of residential building

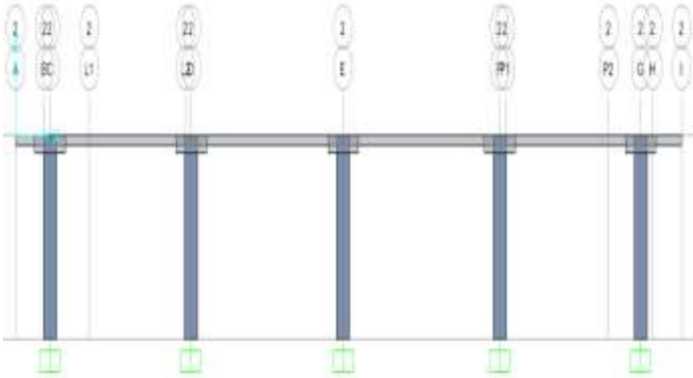


Fig- 2: Sectional elevation

2. ANALYSIS AND DESIGN METHODOLOGY

The design of post-tensioned slab is done by two methods,

- Load balancing method
- Equivalent frame method

2.1 Load balancing method

The concept of load balancing is introduced for pre stressed concrete structures, as per T.Y Lin a third approach after the elastic stress and the ultimate strength method of design and analysis. It is first applied to simple beams and cantilevers and then to continuous beams and rigid frames. This load-balancing method represents the simplest approach to pre stressed design and analysis, its advantage over the elastic stress and ultimate strength methods is not significant for statically determinate structures. When dealing with statically indeterminate systems including flat slabs and certain thin shells, load-balancing method offers tremendous advantage both in calculating and visualizing. According to load-balancing method, pre stressing balances a certain portion of the gravity loads so that flexural members, such as slabs, beams, and girders, will not be subjected to bending stresses under a given load condition. Thus a structure carrying transverse loads is subjected only to axial stresses.

2.2 Equivalent Frame method

The equivalent frame method of analysis is known as the beam method. This method of analysis utilizes the conventional elastic analysis assumption and models the slab or slab and columns, as a beam or as a frame, respectively. This is the most widely used and applied method of analysis for the post-tensioned flat plates.

According to Y. H. Luo, A. Durrani et the effect of vertical of lateral services and design loading on post-tensioned flat plates, bonded or unbonded, may be analyzed as for rigid frames in accordance with the provisions of the code (IS, ACI etc.). When the columns are relatively slender or not rigidly connected to the slab, their stiffness may be neglected and continuous beam analysis applied. As per A.C. Scordelis, Lin, T.Y, and R Itaya et al the moment induced by pre stressing may also be determined by a similar analysis of a rigid frame or continuous beam, using equivalent load or load balancing concept. However it should be kept in mind that the distribution of moments due to loads may differ considerably from the distribution of moments due to pre stressing. Service loads produce very pronounced moments peaks at columns, whereas the moment curve produced by post-tensioning has a more gentle undulating variation of the same form as the tendon profile.

According to A .Pan, and J. P. Moehle the effects of reversed tendon curvature at supports are generally neglected in applying the load balancing method to design of flat plates since the reverse curvature has only a minor influence on the elastic moments (in the order of 5 to 10 percent), and does not affect the ultimate moment capacity. It is necessary to consider reverse tendon curvature tort adequately evaluate the shear carried by the tendons inside the critical section.

2.3 Modeling of structural floor system

In SAFE, tendon essentials are utilized to endow with the PT technique. Diagram represents a plan of the essentials convoluted in counting post-tensioning, from definition of material up- to comprehensive results.

Post-Tensioning - A course of action when the steel tendons are stressed after the concrete casting.

Tendon - It consists of a quantity of high-strength steel wires or strands covered by a duct, sited wherever applicable in the slab or beam. Tendons are a kind of rebar which are inserted in concrete to stand for the end product of post-tensioning. Every tendon is designated as a category of line object between two joints, **i** and **j**. The two ends of the tendon are denoted end I and end J, respectively..

Post-Tension Load- The stresses which the tendon executes on the structure. This includes incorporation with the vertical loads because of profile of tendon and end forces because of anchorages.

Dead load - The structure weight due to gravity, SAFE calculates automatically from sectional parameters and according to material density.

2.4 Analysis and Design Procedure

The SAFE model has been accomplished by all of the properties of material and sectional definitions, prototype (including tendon layouts, profiles, and jacking force assignments), member assignments, and loading criteria have been specified, an analysis is ready to be performed.

While the examination phase, SAFE calculates reactions, displacements, forces, stresses for all particular load patterns and its combinations. Then SAFE the executes a output according to the required code of design and calculates the essential parameters.

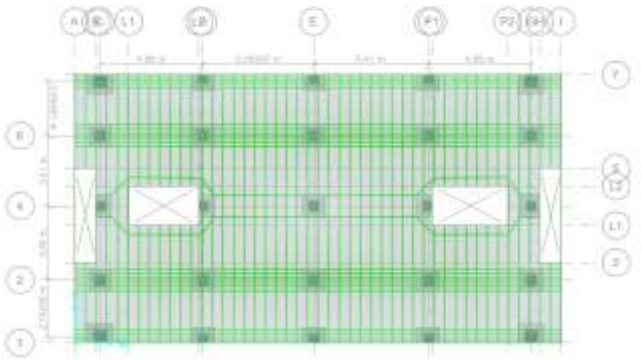


Fig- 3: Tendon layout of residential building for post tensioned flat slab with drop

3. POST TENSIONING TECHNIQUES AND SYSTEMS

3.1 Post-tensioning systems

Post tensioning systems are bifurcated as bonded and unbonded type for fabrication purposes. There are various types of post tensioning systems which are listed below

- Unbonded system
- Bonded system

3.1 Unbonded systems

This setup is immediate for fixing; tendons are deflected easily and to make comfortable with slab shapes by neglecting opening. The system minimizes abrasion and amplified irregularity. Grouting is not required.

It consists of 7 cable strands of 13 mm or 15 mm dia. which are glazed with corrosion preventing grease and encased in high – density polyethylene (HDPE) sheathing.

Tendons are positioned in the slab in order to suit the profiles prior to pouring of concrete. The lubricant minimizes abrasion and the cover permits for free motion of the steel wire around concrete while stressing operation.

Fig- 4: Unbonded monostrand system

3.1 Bonded systems

The setup incorporate groups of 2, 3,4,5 or 6 set of wires enclosed in a tendon in a flat conduit fixed at both end by anchorages.

The conduits are made full by a cement grout mortar to bond the tendons around the concrete inside up to the tendon length. This initiates frictionless medium surrounding to the steel for everlasting decay preservation.

The cables are closed at one end, and can be left exposed at the other end and implanted in the concrete through adequate distance to make sure their bonding. This system needs a lesser quantity of ordinary reinforcing such that bonding permits the strands to make contact with maximum stress at ultimate state.

Fig- 5: Bonded mulitstrand system

4. RESULTS

4.1 Structural results of pt slab with drop

Seismic analysis–Modal analysis showing natural periods and frequencies of pt slab.

TABLE: Modal Periods And Frequencies					
OutputCase	ModeNum	Period	Frequency	CircFreq	Eigenvalue
Text	Unitless	Sec	Cyc/sec	rad/sec	rad2/sec2
MODAL	1	0.066277	15.088	94.802	8987.4
MODAL	2	0.059353	16.848	105.86	11207
MODAL	3	0.057232	17.473	109.78	12052
MODAL	4	0.053144	18.817	118.23	13978
MODAL	5	0.051645	19.363	121.66	14802
MODAL	6	0.050164	19.935	125.25	15688
MODAL	7	0.049516	20.196	126.89	16102
MODAL	8	0.048265	20.719	130.18	16947
MODAL	9	0.046973	21.289	133.76	17892
MODAL	10	0.04609	21.697	136.32	18584
MODAL	11	0.043014	23.248	146.07	21338
MODAL	12	0.041319	24.202	152.06	23123

Table- 1: Frequencies and natural periods

4.2 Diagrams showing stresses for applied loads & its combinations:

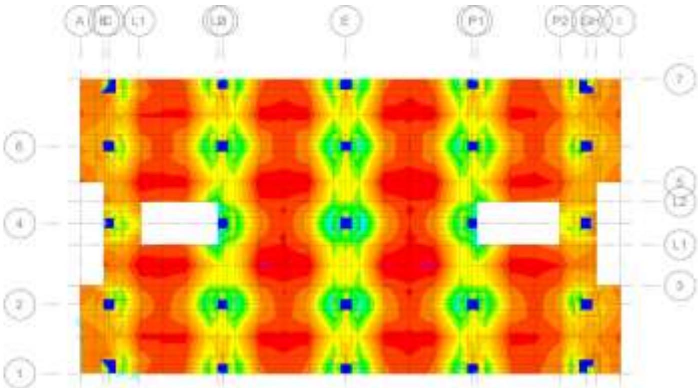


Fig- 4.2 a) Stresses of Dead Load for stresses at top face with maximum of(2.42 N/mm^2) at (5.86m, 5.68m) & minimum of (-0.692N/mm^2) at (15.105m, 4.7875m)

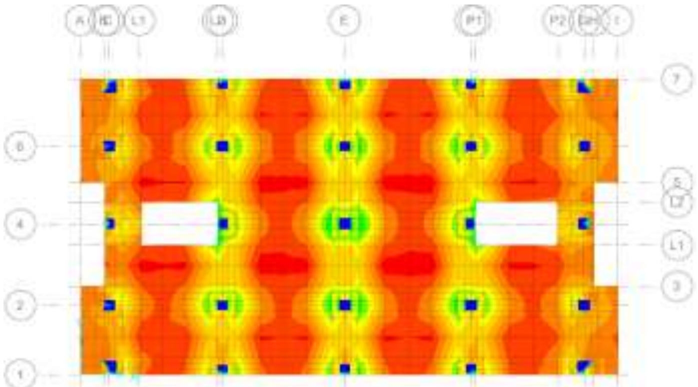


Fig- 4.2 b) Stresses of Live Load for stresses at top face with maximum of(1.063 N/mm^2) at (5.86m, 5.68m) & minimum of (-0.305N/mm^2) at (15.105m, 4.7875m)

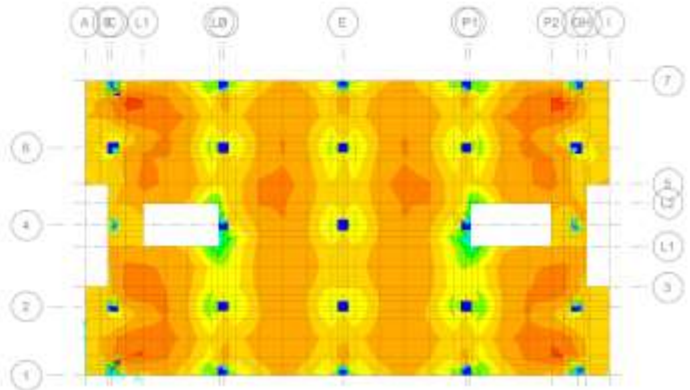


Fig- 4.2 c) Stresses of Load combination {1.5DL+1.5LL+1PT-FIN-HP-1E} for stresses at top face with maximum of (12.9 N/mm^2) at (16.91m , 6.11m) & minimum of (-8.44N/mm^2) at (1.789m , 12.245m)

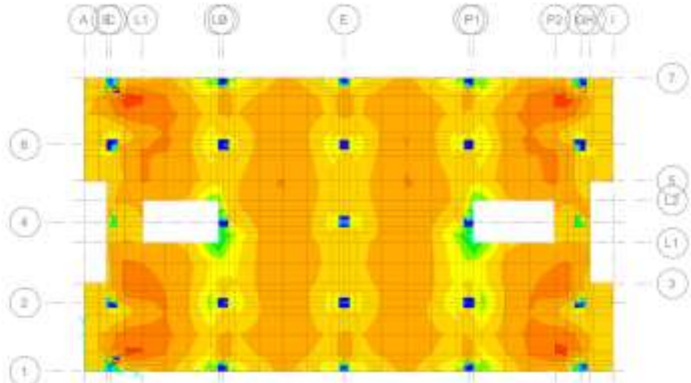


Fig- 4.2 d) Stresses of Load combination {1.5DL+1PT-FIN-HP-1.5E} for stresses at top face with maximum of (11.473 N/mm^2) at (16.91m , 6.11m) & minimum of (-9.28N/mm^2) at (1.789m , 12.245m)

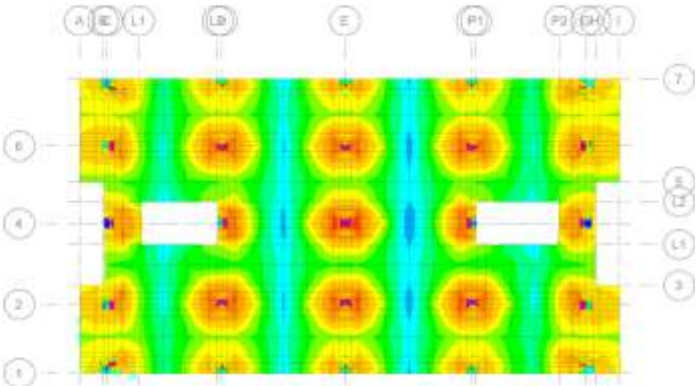


Fig- 4.2 e) Stresses of Dead Load for stresses at bottom face with maximum of (1.468 N/mm^2) at (14.015m, 6.41m) & minimum of (-1.397N/mm^2) at (16.495m, 6.41m)

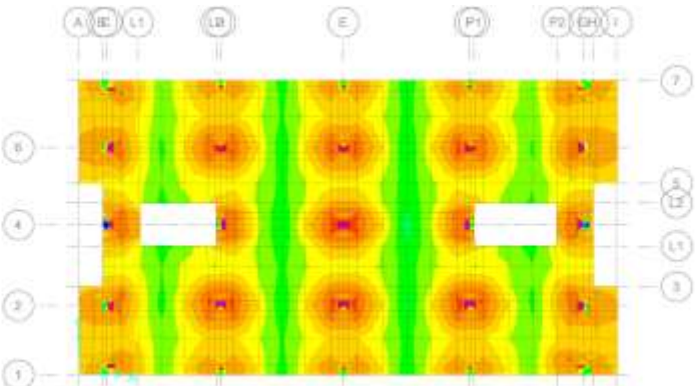


Fig- 4.2 f) Stresses of Live Load for stresses at bottom face with maximum of (0.647N/mm^2) at (14.015m, 6.41m) & minimum of (-0.614N/mm^2) at (16.495m, 6.41m)

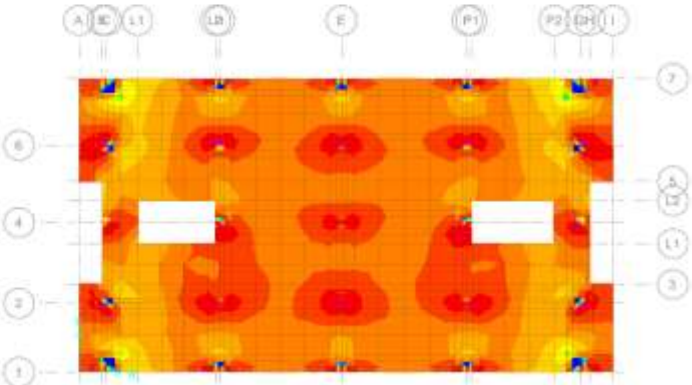


Fig 4.2 g) Stresses of Load combination {1.5DL+1PT-FIN-HP-1.5E} for stresses at bottom face with maximum of (15.216 N/mm^2) at (20.978m , 12.1m) & minimum of (-3.51N/mm^2) at (16.495m , 6.11m)

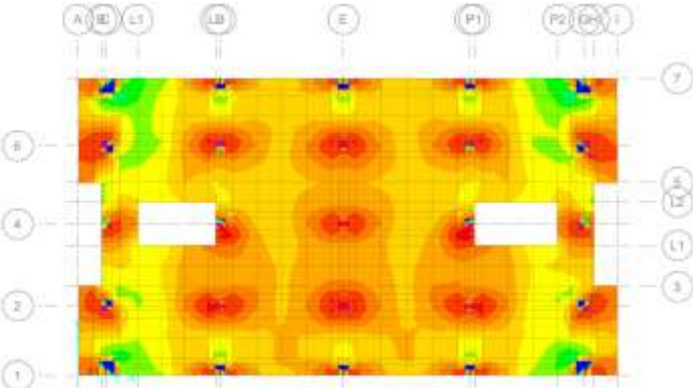


Fig- 4.2 h) Stresses of Load combination {1.5DL+1.5LL+1PT-FIN-HP-1E} for stresses at bottom face with maximum of (14.5 N/mm^2) at (20.978m, 12.1m) & minimum of (-4.473N/mm^2) at (16.495m, 6.11m)

4.3) Diagrams showing strip moment for applied loads & its combinations

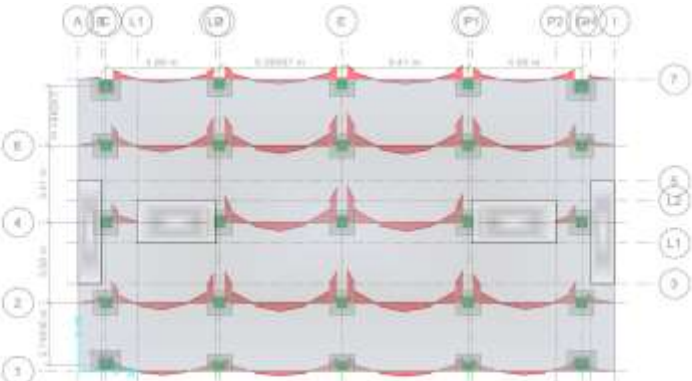


Fig- 4.3 a) Strip moment of Dead Load with maximum of (5.72kN-m/m) at (14.015m, 6.635m) & minimum of (-22.71kN-m/m) at (11.535m, 6.635m)

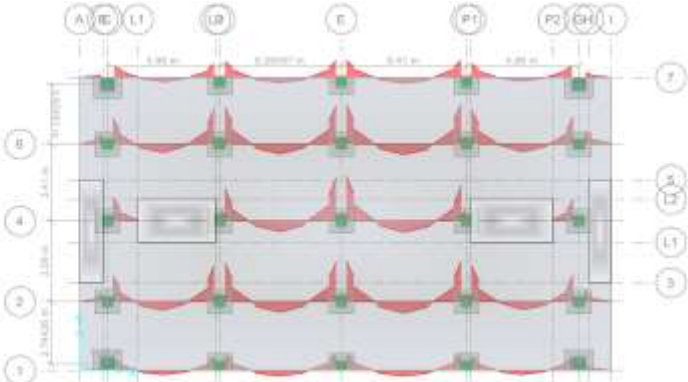


Fig- 4.3 b) Strip moment of Live Load with maximum of (2.522kN-m/m) at (14.015m, 6.635m) & minimum of (-9.97kN-m/m) at (11.535m, 6.635m)

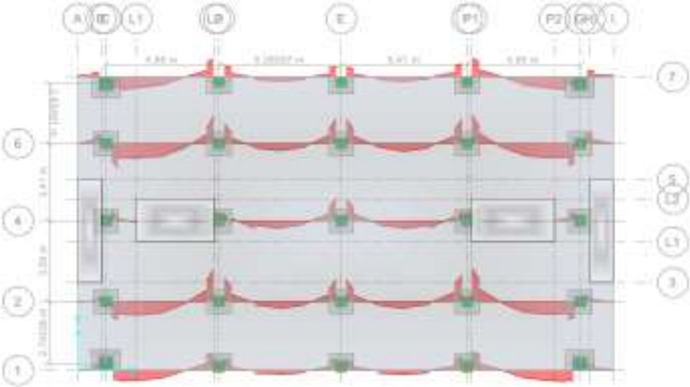


Fig- 4.3 c)Strip Moment of Load combination {1.5DL+1PT-FIN-HP-1.5E} with maximum of (36.72kN-m/m) at (1.72m , 10.045m) & minimum of (-50.26kN-m/m) at (16.945m , 3.05m)

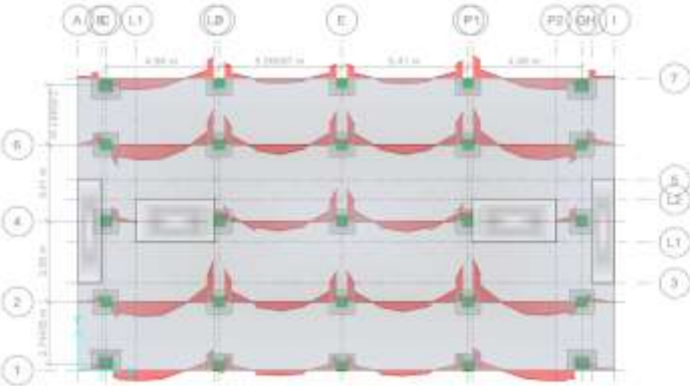


Fig- 4.3 d) Strip Moment of Load combination {1.5DL+1.5LL+1PT-FIN-HP-1E} with maximum of (31.88kN-m/m) at (1.72m , 10.045m) & minimum of (-62.32N/mm^2) at (16.945m , 3.045m)

4.4) Diagrams showing strip shear force for applied loads & its combinations

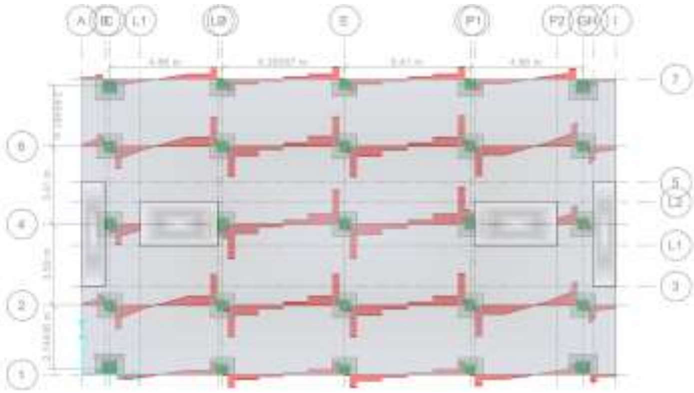


Fig- 4.3 a) Strip Shear force of Dead Load with maximum of (31.94kN/m) at (16.2m, 6.635m) & minimum of (-30.9kN-m/m) at (6.628m, 6.635m)

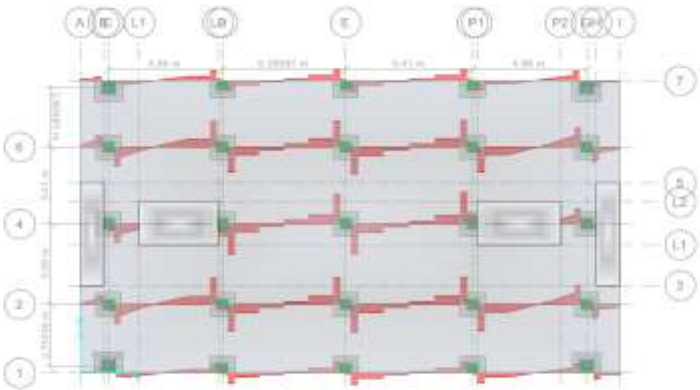


Fig- 4.3 b) Strip Shear force of Live Load with maximum of (13.94kN/m) at (16.2m, 6.635m) & minimum of (-13.95kN-m/m) at (6.275m, 6.635m)

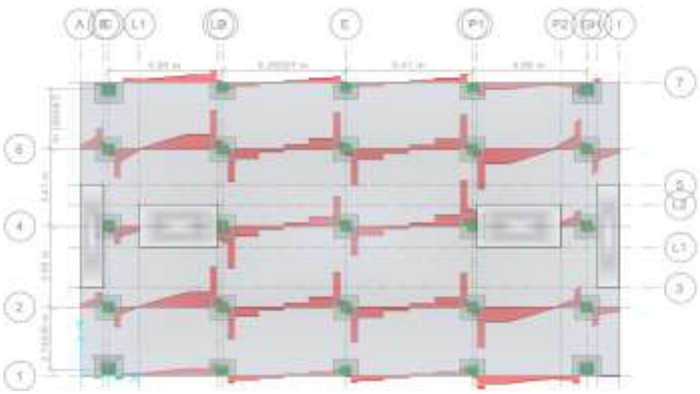


Fig- 4.3 c)Strip Shear force of Load combination {1.5DL+1PT-FIN-HP-1.5E} with maximum of (65.42kN/m) at (16.19m , 6.635m) & minimum of (-61.02kN/m) at (6.28m , 6.635m)

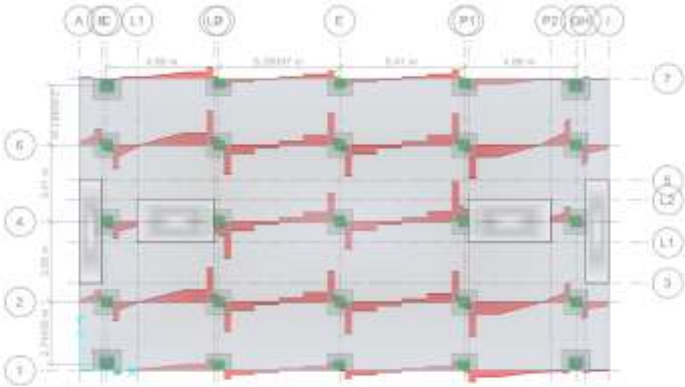
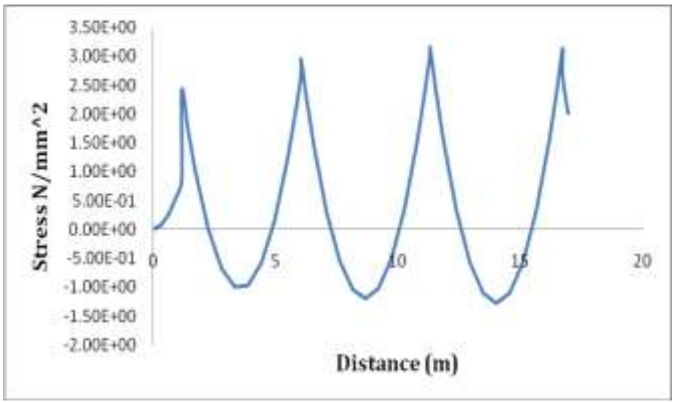
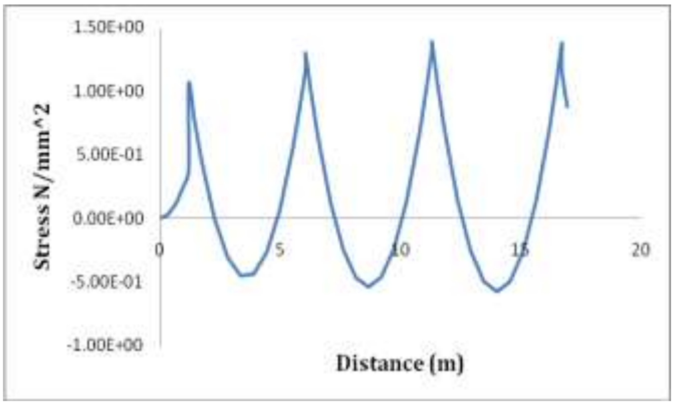


Fig- 4.3 d)Strip Shear force of Load combination {1.5DL+1.5LL+1PT-FIN-HP-1E} with maximum of (86.33kN/m) at (16.19m , 6.635m) & minimum of (-81.25kN/m) at (6.28m , 6.635m)

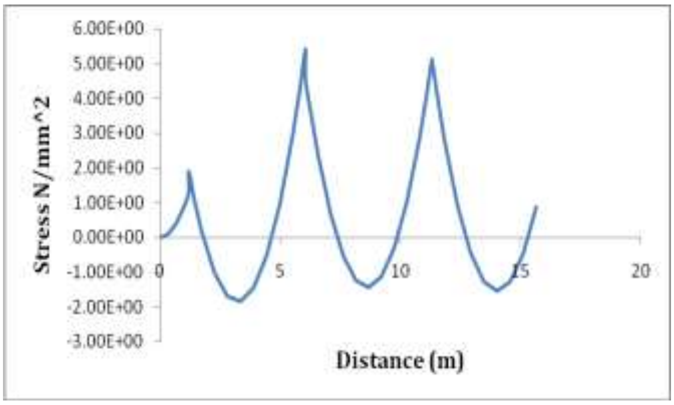
4.4) Equivalent frame analysis results



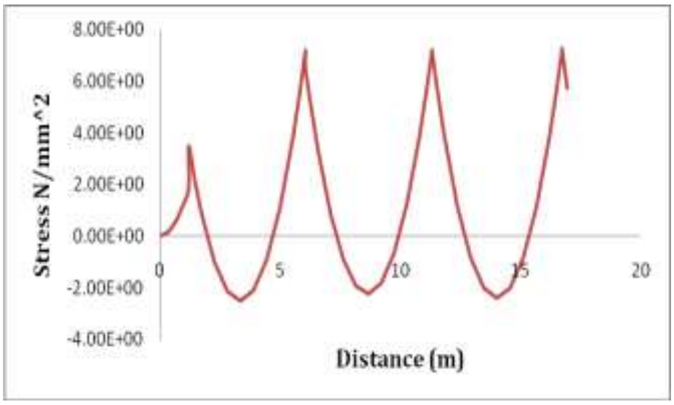
4.4.a) Graph showing variation of Stress along Distance for Dead load



4.4. b) Graph showing variation of Stress along Distance for Live load



4.4. c) Graph showing variation of Stress along Distance for load combination {1.5DL + 1PT-FIN-HP -1.5E}



4.4. d) Graph showing variation of Stress along Distance for load combination {1.5DL+1.5LL+1PT-FIN-HP-1E}

5. CONCLUSIONS

This chapter presents the conclusions that are concluded depending upon the study executed. Further the scopes for future work have also been discussed.

- CSI SAFE software has got a new approach for EQUIVALENT FRAME ANALYSIS for PT slab than any other civil software.
- EQUIVALENT FRAME MODEL (EFM) analysis tool in SAFE software analysis the PT slab as per the design strips provided while modeling.
- Each individual strip is analyzed separately in EFM analysis for more accurate and better results than compared to overall basic analysis.
- PT slab with drop helps to reduce the stress concentration in the slab and column junctions.
- High strength tendons provided in the slab resists the stresses induced due to due to self weight and varying dynamic loads (live load).
- Due to parabolic profile of tendons provided as main reinforcement and reverse parabolic profile of tendons provided in distribution direction of slab nullifies the secondary moments arisen in the slab.
- Because of tensioning of flat plate slab there is no effect at great extent on axial force but shear and moment on column increases.
- The curvature at middle of flat plate slab is handled high efficiently by parabolic and Trapezoidal tendon than triangular tendon.
- EFM method is also applicable when the columns are quite slender, not rigidly linked or stiffness of the column is neglected.
- The moment calculated for Post-tensioned flat plate slab is less when compare to moment calculated for RCC flat plate slab by equivalent frame procedure because as depth of Post tensioned flat plate slab 30 to 35% less than RCC plate slab, due to which self weight of slab get reduced.
- The stresses calculated by strip method are greater than stresses calculated by equivalent frame method. Hence EFM gives most economical sections for the designers.

5.1) Scope for future work:

The study presented here can be improved further by considering various other factors of analysis also some of which are listed below:

- Further analysis can be carried out by providing different profile for tendons such as partial parabola-left, partial-right, trapezoidal, etc.
- Analysis of PT flat slab with drop is also done by time history analysis, equivalent static analysis, and response spectrum analysis other than push over analysis.
- Even analysis can also be done using finite element method.
- It can be analyzed using different software such as STAAD-pro, ETABS, ANSYS, and ADAPT.etc.

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