Global Scientific JOURNALS
GSJ: Volume 8, Issue 10, October 2020, Online: ISSN 2320-9186
www.globalscientificjournal.com

Finite Element Modeling of Long Span Post-Tension Two Way Concrete Slab under Flexural Loading

Ermias Shimelis Lakew

Department of civil engineering, Faculty of technology, Addis Ababa science and technology university, Addis Ababa ,Ethiopia

college of architecture and civil engineering

Email address:
ermiasshimelis@gmail.com, ermiaslakew@yahoo.com

To cite this article:

Ermias Shimelis Lakew. Finite Element Modeling of Long Span Post-Tension Two Way Concrete Slab under flexural loading

. *International Journal of XXXXXX.* Vol. x, No. x, 2017, pp. x-x. doi: 10.11648/j.xxx.xxxxxxxx. xx.

Received: MM DD, 2020; **Accepted**: MM DD, 2020; **Published**: MM DD, 2020

Abstract: Nowadays, in our country design of modern an architectural building structures requires the use of slender and free from numerous supports slabs. The most suitable solution for above requirements is the post-tensioned slabs with bonded tendons. Slabs prestressed by bonded tendons are successfully used worldwide for several decades. During that time many recommendations dealing with the forming of geometry and prestressing, dimensioning and erection technology were issued. During the recent years Post-Tensioned (PT) method is a widely used technique to prevent cracking and to minimize the deflection which is resulted by loads. In this method, stress is applied after concrete placing and reach adequate hardening and strength.

In spite of designed the slabs significantly larger and slenderer than the recommended maximum value of span and span to depth ratio, the deflection of the slabs is definitely far from the limit value.

This thesis investigates the detailed flexural behavior analytical investigation of specific long span post tension two-way concrete slab under flexural loading. ANSYS non-linear finite element analysis software is used to develop full scale 3D two way post tensioned concrete slab model to investigate the flexural behavior of long span PT slab with specific number of tendons and the applied load on the concrete two-way slab. Further, a parametric study will conduct to investigate the effect of tendons layout and span length on the overall behavior of post -tensioned two-way concrete slab.

Keywords: Post Tension **,**Tendons, Unbonded, Microplane, Tendons layout, Long span

---

1. Introduction

Design of modern an architectural building structures requires the use of slender and free from numerous supports slabs which is longer span concrete slab. The most suitable solution for above requirements is the post-tensioned concrete slabs with unbonded tendons. Slabs prestressed by unbonded tendons are successfully used worldwide for several decades. During that time many recommendations dealing with the forming of geometry and prestressing, dimensioning and erection technology were issued.[1]

Post-Tensioned (PT) method is a widely used technique. Pre-stressing the concrete by using post-tensioned reinforcement provides less cracking and smaller crack widths, causing better durability of concrete structures and preventing corrosion problems. Furthermore, pre-stressing leads to smaller deflections and allows for more slender structures and smaller overall construction heights. The concrete is prestressed by inserting post-tensioning reinforcement, which applies compressive stresses to the concrete. The compressive stresses are applied with a beneficial size and distribution in order to balance the effects of the external loads. Post-tensioned flat slabs are commonly used in industrial buildings, parking garages and other structures where large open areas are required. In comparison to normal reinforced concrete, post-tensioning allows for reduced slab thickness and larger spans. In this method, stress is applied after concrete placing and reach adequate hardening and strength.

The behaviors of post-tensioned concrete elements were studied experimentally by Williams and Waldron [2], Yang, K. H et al.[3], Ranzi, G et al., [4], Bailey and Ellobody, [5] and others. A collection of studies by several researchers explains the FE analysis of the behavior of reinforced concrete structures such as shear failure of slabs, cyclic loading of columns, and the behavior of structure to seismic and bond models between concrete and steel.

Thomas H.-K. et al., [6] Prestressed concrete is essential in many applications today in order to fully use concrete compressive strength, and through proper design, to control cracking and deflection. Generally, Prestressed concrete can be constructed in one of three ways: pretensioned prestressed concrete, Unbonded post-tensioned (PT) prestressed concrete, and bonded PT prestressed concrete. Although design methods have been developed for prestressed concrete over many decades, the understanding of structural mechanism in PT concrete members still needs to be greatly enhanced in many aspects such as shear-flexure interaction in PT two-way slab systems. Furthermore, studies of discrepancy between bonded and unbonded two-way slab systems were Rarely reported. Only a few studies have compared the behaviors of PT concrete one-way members with different tendon systems or tendon bonding conditions.

Abbas et al., [7] investigates the structural behavior of PT two-way concrete slabs which involves flexural behavior analytical investigation of PT concrete two-way slab with the different bonded tendon layout. To study their structural behavior, they used non-linear Finite Element (FE) analysis programs method, to choose the most effective and optimum position of tendon layout with different number of tendons and applied load on the concrete two-way slab.

Nethravathi S.M, et al., [8] this paper includes result on a study of un-bonded post tensioned cast-in-place parking floor subjected to various arrangements of tendon layout based on FEM analysis. The Modelling and analysis of post-tensioned flat plate is done by using SAFE software. Equivalent loads based on cable profiles are applied to the flat plate according to the tendon layout. Design moments, service moments, hyper-static moments, short term deflection, long term deflection, and punching shear are compared for the various tendon layouts at service and ultimate limit state.

S. W. Han et al., [9] this research investigates the cyclic behavior of interior post-tensioned flat plate connections. Cyclic tests of four interior PT slab–column connections were conducted. Primary test variables were the level of gravity shear at the slab–column connection and the slab tendon arrangement. Test results indicate that both the test variables strongly influence the cyclic behavior of the PT connections, and that the use of slab bottom reinforcement at the slab–column connection was effective in resisting positive moment developed under lateral loading as well as improving the hysteretic energy dissipation capacity. Experimental studies of four isolated, post-tensioned interior slab–column connections subjected to both gravity and cyclic lateral loading were conducted. Based on the test results, the following conclusions are reached.

Mark Sarkisian et al., [10] Post-tensioned (PT) flat-plate gravity framing systems are highly efficient and reduce embodied carbon when compared to conventional reinforced concrete framing systems. Efficiency is especially apparent in multi-span applications with regular orthogonal support arrangements. Even though PT flat-plate gravity framing systems are less efficient in single-span or irregular support applications, they are being still useful in reducing slab thickness, improving construction efficiency, and reducing seismic mass.

Matthew J. Davey, [11] investigates the performance of exterior post-tensioned wide band beams and column joints under seismic loading. This investigation involved the testing of two specimens, designed and detailed for gravity loading to Australian standards and construction practices without any specific seismic detailing. One of these specimens was repaired using carbon fiber reinforced polymer and re-tested. The second specimen had the tendons in the beam concentrated closer to the column joint. Both the original specimens and the repaired specimen were able to achieve drift capacities greater than would be expected to be imposed on them in low to moderate seismicity regions, and greater than drift limits imposed by many design codes, without significant loss of capacity. The use of post-tensioned tendons resulted in larger achievable displacements, ductility and energy dissipation compared to similar ordinarily reinforced wide beam tests. Both test specimens performed very similarly to each other, indicating that the tendon spacing was not significant. Finite element modelling was conducted for both specimens, with good comparison to experimental results being obtained. These models were then used as the basis for a parametric analysis, which identified edge beam size and ligature spacing, as well as level of prestressing and reinforcement positioning, as the key performance points and areas for future research.

U. Prawatwong, et al., [12] this paper presents an experimental study on the seismic performance of two three-fifth scale post-tensioned (PT) interior slab-column connection models, one without drop panel and another one with drop panel. The model without drop panel was designed and constructed to represent a typical connection between interior column and post-tensioned flat plate with bonded tendons usually found in Thailand.

The other model was intended to represent an improved design of typical post-tensioned slab-column connections by using drop panel. Both models were tested under a constant gravity load. A conventional displacement-controlled cyclic loading routine with monotonically increasing drift levels until failure was adopted to investigate the seismic performance.

Shriraj S. Malvade et al., [13] this paper gives a review on the response and behavioral properties of Post-tensioned flat slab during earthquake and compare with normal flat slab. The behavior and response of flat slab and Post tensioned flat slab during earthquake is an important aspect which needs to be explored. The use of post-tensioned flat slab is increasing widely, due to its advantages over traditional concrete. These slabs have been proved to be the most economical when compared to the RCC slabs. As these slabs are very easy to construct, Post-tensioned slabs are preferred for industrial, commercial and residential floor slab construction. Majorly because of the relatively thin slab depths, lighter in weight and smaller floor to floor heights, Post-tensioned slabs have been used for such construction.

2. Finite element modeling

For the present research ANSYS Mechanical APDL 19.3 is being used. It is very accurate in predicting the cracks and crushing behavior of the reinforced concrete. Modeling is one of the most important aspects for the FE analysis. Accuracy in the modeling of element type and size, geometry, material properties, boundary conditions and loads are absolutely necessary for close numerical idealization of the actual member. Modeling the complex behavior of reinforced concrete, which is anisotropic and nonhomogeneous, is a difficult challenge in the FE analysis Of Civil engineering structures. So, it should be done with very care and patience. Few of the basic theory must be followed before going for the modelling in ANSYS19.3 specially of the concrete modelling. One major problem which has been encountered by the engineer/scientists working in the FEM of concrete is the convergence problem associated with it. Due to cracks, concrete is generally not able to converge so some of the convergence criteria has to be dropped to get the accurate results.

2.1. Element Types

The following were the element types used in the simulation (ANSYS Mechanical
APDL 19.3)

- CPT215 for concrete
- REINF264 for discrete reinforcing
- SOLID185
- MESH200
- INSTATE

2.1.1 CPT215 Element

The ANSYS R19.3 Parametric Design Language (APDL) was used to analyze all modeled slabs. CPT215 element type (or 3-D reinforced concrete solid) and microplane coupled damaged plasticity (CDP) material model in ANSYS was used to model the concrete. CPT215 is a 3-D eight-node coupled physics solid element capable of modeling coupled physics phenomena such as structural-pore-fluid-diffusion-thermal analysis and structural implicit gradient regularization using a nonlocal field. The element is defined by eight nodes and can have the following degrees of freedom at each node: Translations in the nodal x, y, and z directions Pore-pressure, Pore-pressure (PRES), Temperature (TEMP), Nonlocal field values (GFV1, GFV2).

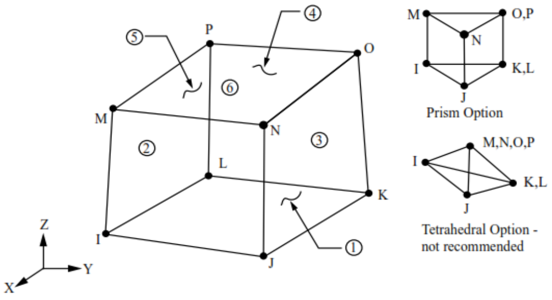


Figure 2.1 CPT215 Structural Solid Geometry

2.1.2. REINF264 Element

REIF264 element type is used for rebar steel spare element with standard 3-D link, beam, shell and solid elements (referred to here as the *base elements*) to provide extra reinforcing to those elements. REIF264 allows tension-only or compression-only reinforcing fibers. The REIF264 element does not accept element loading the reinforcing element is firmly attached to its base element. No relative movement between the reinforcing element and the base is allowed.

2.1.3. SOLID185 Element

SOLID185 is used for 3-D modelling of solid structures. It is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, hyper elasticity, stress stiffening, creep, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elastoplastic materials, and fully incompressible hyper elastic materials.

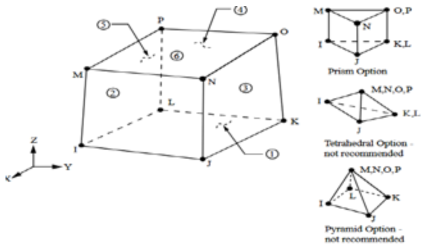


Figure 2.2 Solid185 geometry

2.1.4. MESH200 Element

MESH200 is a "mesh-only" element, contributing nothing to the solution. This element can be used for Temporary representation of discrete reinforcing fibres and smeared reinforcing layers, including their geometry, material, and orientation. In this research the Mesh200 element options are used for modelling of reinforcing 3-D Lines with two or three nodes for discrete reinforcing in 3-D model. MESH200 may be used in conjunction with any other ANSYS element types. After it is no longer needed, it can be deleted (cleared), or can be left in place. Its presence will not affect solution results.

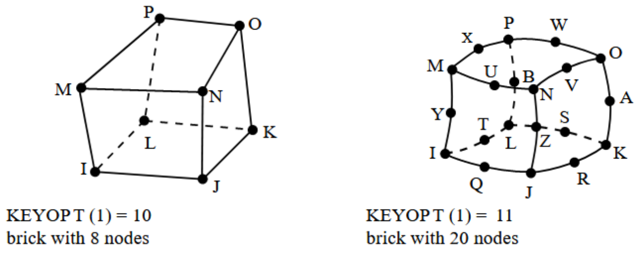
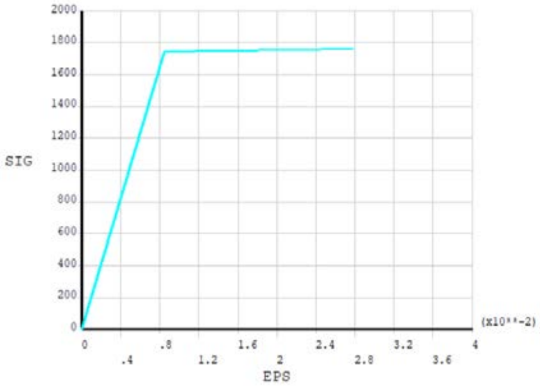
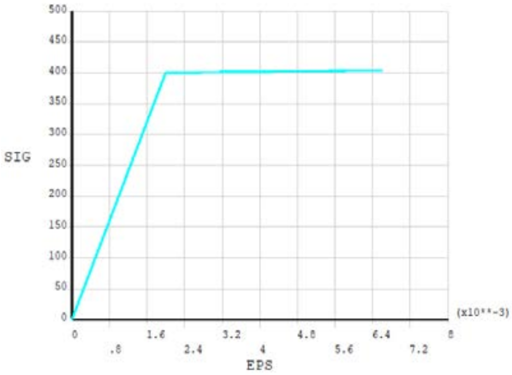


Figure 2.3: Mesh200 geometry

In the current study, for the compression of concrete, the bilinear relationship of stress-strain is adopted. The considered stress-strain relation depends on the study conducted by (Desayi and Krishnan, 1964); as shown by the Figure 2.4 (a) The Stress-strain curve of the isotropic bilinear model for tendons and for modeling the reinforcing steel bars of the current study, the bilinear relationship of stress-strain showed in Figure 2.4 (b). Is taken into consideration. Steel bars were assumed to transmit only axial force because they are slender, while in the current study, the strands are assumed bilinear isotropic.



(a) Stress-strain curve of the isotropic bilinear model for tendons



(B) Stress-strain curve of the isotropic bilinear model for steel rebar

Figure 2.4. Stress- strain curve for bilinear model for rebar , tendons and concrete

3. Finite Element Validation Analysis of PT slab

The numerical results were verified by comparison with the experimental results. In order to validate the developed nonlinear models, one of the onsite erected building post tensioned concrete two-way slab onsite tested by Rafal Szydlowski and Barbara Labuzek [2] was chosen. One of the Artistic and Cultural Center in Kozienice P1-2 tested under static load up to failure. P1-2 had tendons one directions with seven wire steel strands with a 5 mm diameter non-prestressed bars which was used in one direction at top of slab for each 250 mm spacing, with overall slab geometry dimensions equal to 4000 mm, 3000 mm and 250 mm length, width and thickness respectively as shown in Figure 3.1 The non-prestressed reinforcement was made of high tensile steel deformed bars with a 400 MPa yield stress and 200 GPa modulus of elasticity. The tendon nominal ultimate tensile strength was 1860 MPa. The tendon layout applied similarly to the bending moment induced from the concentrated loads. The tendons were unbonded with 220 MPa prestressing force. Figure 3.1 demonstrates the dimensions and section details of the prestressed slab specimen. Figure 3.2 shows the concrete and tendons mesh.

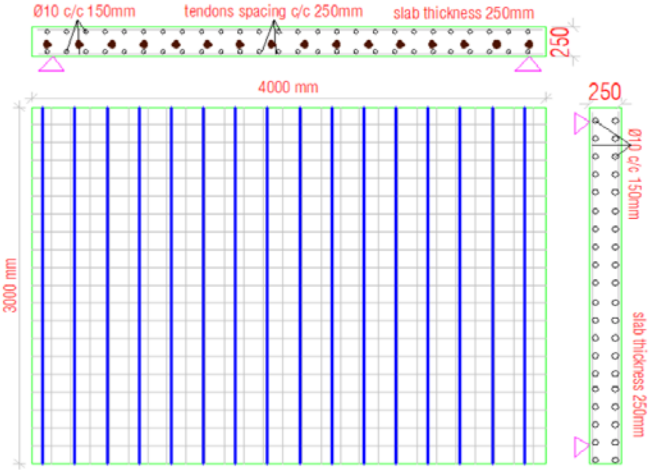


Figure 3.1 Detailing of onsite specimen P1-2 by (Rafal Szydlowski and Barbara Labuzek, 2017)

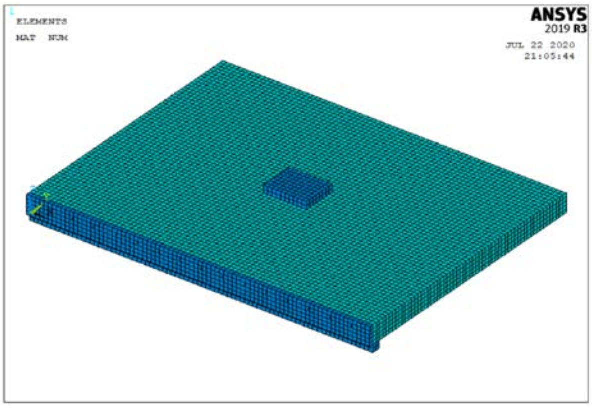


Figure 3.2 Finite element mesh of the tendons anchore plate ,loading plate, and supporting plate of the concrete two-way slab P1-2

After modeling and analyzing the experimental model slab P1-2 by ANSYS program, the results for load displacement curves were validated and showed good Agreement with experimental results as shown inFigure3.2

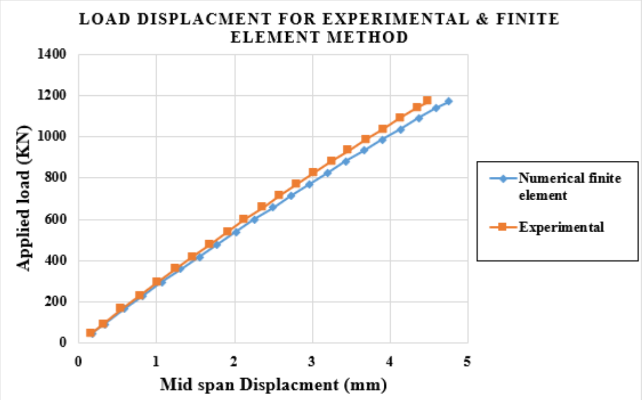


Figure 3.3 Load vs. deflection curves for the numerical finite element slab P1-2

3.1 Parametric Study of post tension slab

3.1.1Tendons Layout for different span length

Prestressing is a way of counteracting the effect of external loads on structures by imposing stresses conflicting to the load effect. The best way to achieve this is by using tendons, which stressed prior to the final loading of structures. Tendons are typically located near the bottom which positive moments occur and near the top which negative moments occur with the intent to install the cable with the maximum total drape. In this study different tendon layout with different long span length are considered which are PT tendons in one direction with different span length and PT tendons in two directions with different span length as shown in Figures 3.6 For all cases tendon profiles are straight at the bottom, and spacing between tendons equal to 400 mm and span length of 8m, 10m, 12m, 15, and 18m.

The dimensions, loading, and boundary conditions considered for the modeling slab are shown in Figures 3.4 and 3.5 The slab was subjected to concentrated point load at center and simply supported at all ends. In the current study, using 3D solid elements, the unbonded PT concrete slab was modeled. Only 1/4 of the slab was modeled because of symmetry. The concrete material properties, reinforcements, and strands for bonded PT two-way slabs considered in this study are shown in Table 3.1

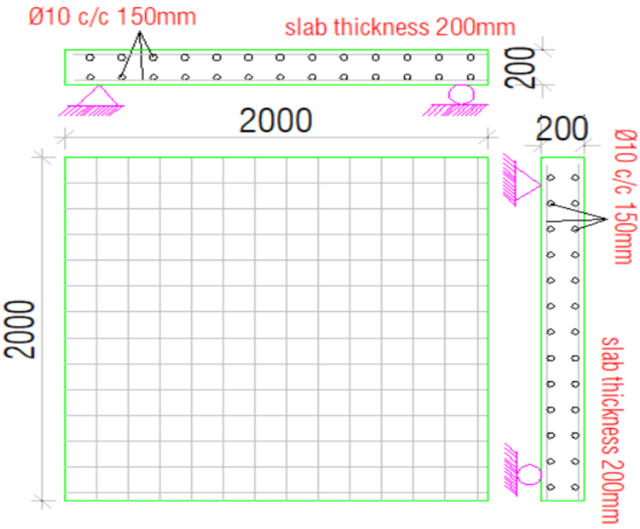


Figure 3.4 Concrete two-way slab dimension and cross section for one of the parametric study

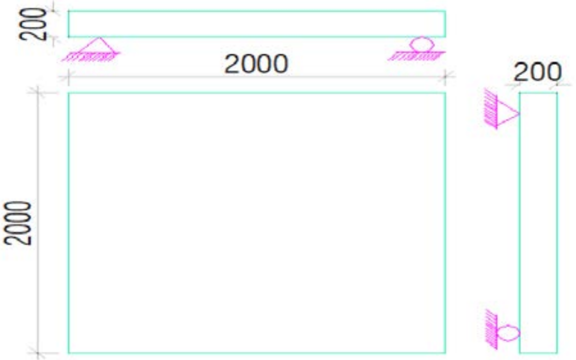
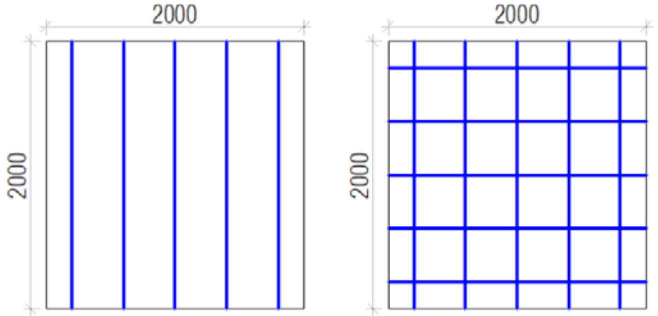


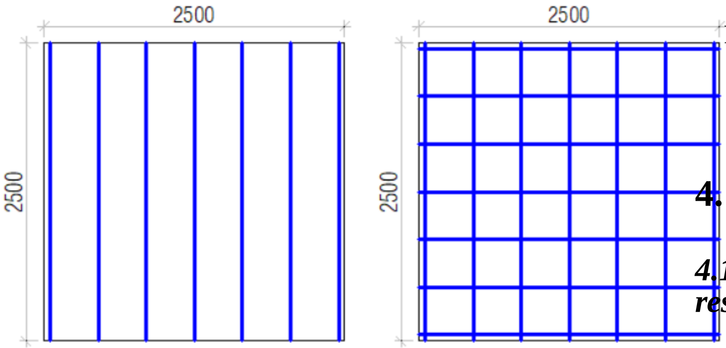
Figure 3.5. Boundary condition (simply supported)

Table 3. 1 material properties

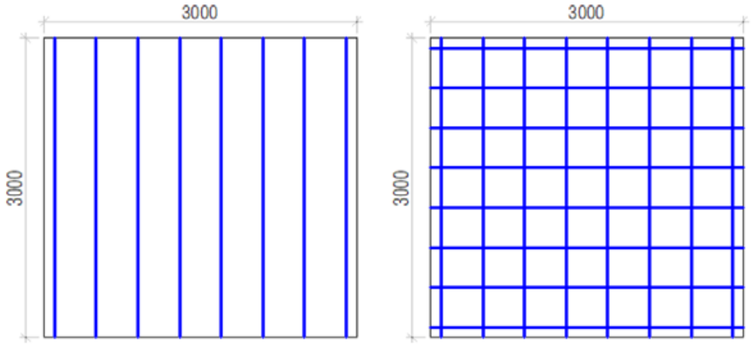
Material	Properties			
Pre stressed Steel tendons	Linear Isotropic		Elastic Modulus	2.0629E+05Mpa
			Poisson's Ratio	0.3
	Bilinear Isotropic		Yield Stress	1741 Mpa
			Tang Mod	1000 Mpa
Mild steel rebar	Linear Isotropic		Elastic Modulus	2E+05 Mpa
			Poisson's Ratio	0.3
	Bilinear Isotropic		Yield Stress	400 Mpa
			Tang Mod	1000 Mpa
Concrete	Density		dens	2.5
	Linear Isotopic		Elastic Modulus	34E+3 Mpa
			Poisson's Ratio	0.2
	Microplan model	C1	Uniaxial compressive strength	45 Mpa
		C2	Biaxial compressive strength	51.75 Mpa
		C3	Uniaxial tensile strength	3.82 Mpa
		C4	tension cap hardening constant	1
		C5	Hardening material constant	4000
		C6	Intersection point abscissa Between compression cap and Drucker-Prager yield function	-31.5



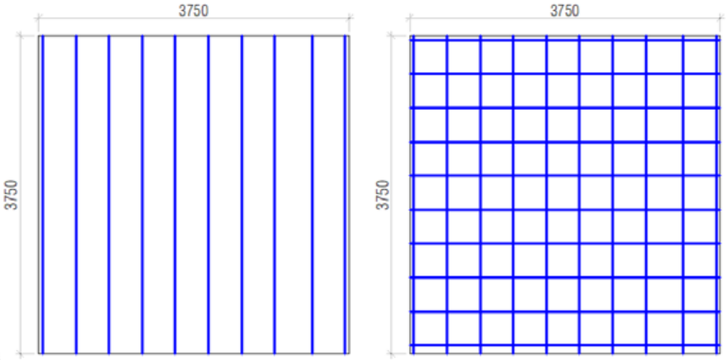
a) PT1-1, span length 8m   b) PT1-2 span length 8m



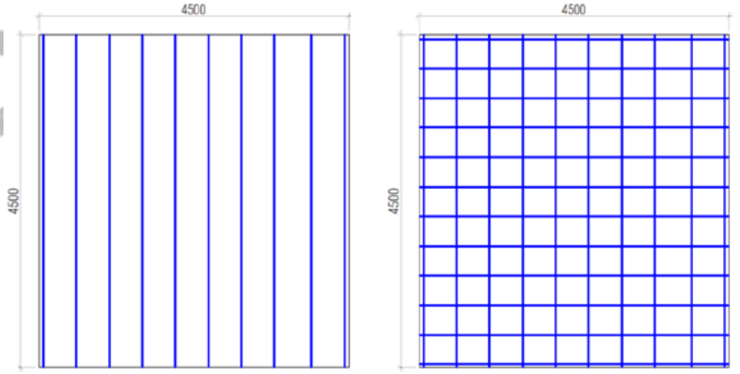
c) PT2-1, span length 10m   d) PT2-2 span length 10m



e) PT3-1, span length 12m   f) PT3-2 span length 12m



g) PT4-1, span length 15m   h) PT4-2 span length 15m



i) PT5-1, span length 18m   j) PT5-2 span length 18m

Figure 3.6 ¼ Model of different span length PT slab and Tendon Layouts

4. Results and Discussion

4.1 Effect of Tendons layout on load-displacement responses results

In this study the effect of tendons layout conducted through ANSYS19.3 nonlinear analysis of PT slab models of twelve different slab specimen with tendons area of 150mm^2, for span length 8m,10m,12m, and 15m tendons runs in one direction and two direction considered in current study. The analysis results are discussed in the following subsection based on load displacement response, stress intensity, and plastic strain results of ANSYS mechanical APDL19.3.

Figure 4.2 shows for tendons layout run in one direction effects on load - displacement responses resulted a failure load of 1930.82KN ,1929.65KN , 1608.04KN, 1286.43KN and 1072.03KN for span length 8m,10m,12m, 15m ,and 18m respectively it shows failure load decrement of 0.06% , 16.67% , 20% , and 16.67% with respect to increment of the span length of the specimen and corresponding displacement of 9.03mm, 11.04mm,13.25mm,16.56mm, and 19.87mm, at failure load.

For tendons layout run in two direction effect on load - displacement responses resulted in failure load of 2088.86KN ,2000.79KN , 1667.33KN, 1333.86KN, and 1111.56KN for span length 8m,10m,12m, 15Mm, and 18m respectively it shows failure load decrement of 0.05% ,16.7% ,20.1% , and 16.2% with respect to increment of the span length of the specimen and corresponding displacement of 8.82mm, 8.98mm,10.77mm, 13.46mm ,and 16.16mm, at failure load.

Figure 4.1 shows load - displacement responses result on failure load for span length of 8m effects of tendons layout which runs in one direction and two direction with failure load of 1930.82KN and 2088.86KN respectively it shows tendons which runs in two direction has failure load increment of 7.56% and their corresponding displacement of 9.03mm, and 8.82mm, at failure load.

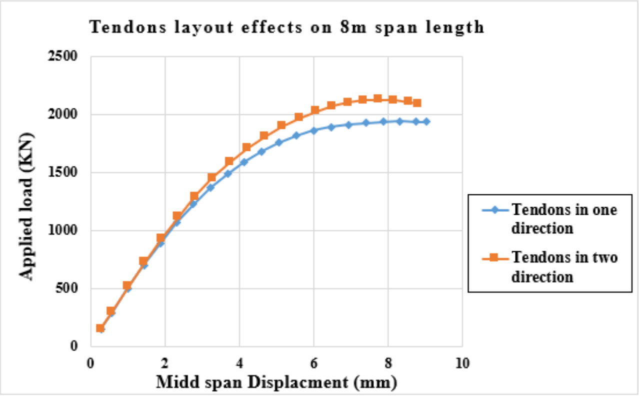


Figure 4.1 Load- displacement curves at the center of slabs for tendons in one & two direction

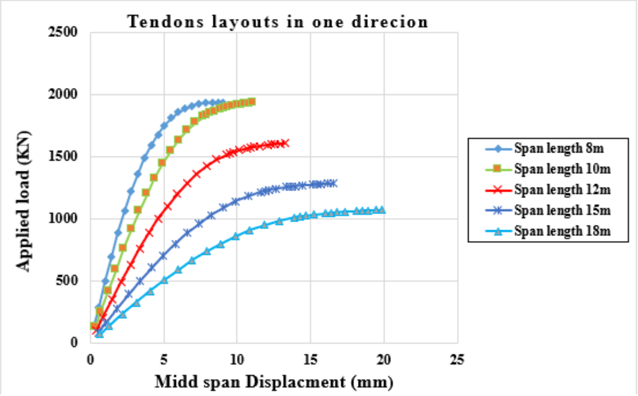


Figure 4.2 Load- displacement curves at the center of slabs for one-direction tendons

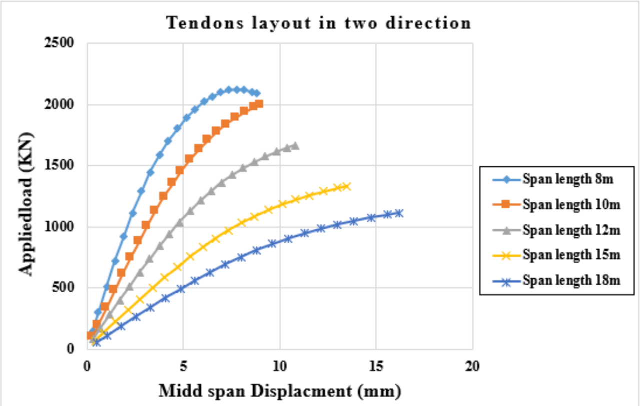


Figure 4.3 Load- displacement curves at the center of slabs for two-direction tendons

Table 4. 1 Failure load and maximum deflection of specimen with different tendons layout

	Specimen (ID)	**support**	**Span length (m)**	**Tendon Spacing (mm)**	**Tendons area (mm^2)**	**Max. deflection (mm)**	**Failure load (KN)**
G1	Tendons in one direction						
	PT1-1		8	400	150	-9.03	1930.82
	Tendons in two direction						
	PT1-2		8	400		-8.82	2088.86
`	Tendons in one direction						
G2	PT1-1	Simply supported	8	400	150	-9.03	1930.82
	PT2-1		10	400		-11.04	1929.65
	PT3-1		12	400		-13.25	1608.04
	PT4-1		15	400		-16.56	1286.43
	PT5-1		18	400		-19.87	1072.03
G3	Tendons in two direction						
	PT1-2	Simply supported	8	400	150	-8.82	2088.86
	PT2-2		10	400		-8.98	2000.79
	PT3-2		12	400		-10.77	1667.33
	PT4-2		15	400		-13.46	1333.86
	PT5-2		18	400		-16.16	1111.56

The most important factor affected long span PT concrete two-way slab behavior was tendon layout and its area. The nonlinear FE analysis was achieved to find the optimum layout of the tendon for long span PT slab. From the FE analysis, it can be noted that the ultimate load capacity; The PT slabs with 8m span length with 400mm tendons spacing in two direction showed stiffer response and highest ultimate load capacity compared to the slabs with highest span length. Using tendon in both directions has the eccentricities specified values. Eccentricity is defined as the distance between the neutral axis and tendons, which creates an internal moment act in the opposite direction of moments caused by the external and prestressing load. The Increase in eccentricities will cause an increment in tendon stresses and decrease the tensile stress in concretes. The use of tendons in two directions creates a transverse effect to increase capacity against counteract external load, with the effect of axial, bending and shear. In addition, straight bottom tendons in two directions of the slab give maximum failure load; it is stronger as compared to other slabs.

4.2 Effect of Concrete Grade on load-displacement responses results

To study the effect of concrete strength the parametric investigation conducted on fifteen models of the PT slab with tendons layout in one direction and spacing of the tendons 400mm with concrete strength C40/50, C35/45, and C30/37 for varies span length the analysis results are discussed in the following subsection based on load deflection, stress intensity, maximum deflection and plastic strain results of ANSYS19.3.The concert grade effect on load - displacement responses ANSYS result of nonlinear analysis of the PT slab with load displacement response resulted in failure load for concrete grade C40/50 with span length of 8m, 10m, 12m, 15m and 18m has 2853.49KN ,2495.32KN ,2079.43KN , 1663.55KN and 1386.29KN respectively it shows failure load increment of 12.55% ,14.57% , 19.99%, and 16.67% with respect to increment of the span length of specimen and corresponding displacement of 8.922mm, 8.965mm ,10.16mm ,12.69mm, and 15.24mm at failure load. The failure load decreased for the concrete grade of C30/37 with increasing of the span length.

The failure load for concrete grade C35/45with span length of 8m, 10m, 12m, 15m and 18m has 2677.63KN ,2568.KN ,2140KN , 1712KN and 1426.67KN respectively it shows failure load increment of 2.86% ,16.7% , 20%, and 16.69% with respect to increment of the span length of specimen and corresponding displacement of 9.02mm, 10.733mm ,12.88mm ,16.1mm, and 19.32mm at failure load. increment of the failure load are observed with increment of the concrete grade from C30/37, C35/45 and C40/50.

The failure load for concrete grade C30/37 with span length of 8m, 10m, 12m, 15m and 18m has 2301.69KN ,2233.47KN ,1861.23KN , 1488.98KN and 1240.82KN respectively it shows failure load increment of 2.96% ,16.7% , 20%, and 16.69% with respect to increment of the span length of specimen and corresponding displacement of 9.08mm, 10.89mm ,13.06mm ,16.33mm, and 19.59mm at failure load.

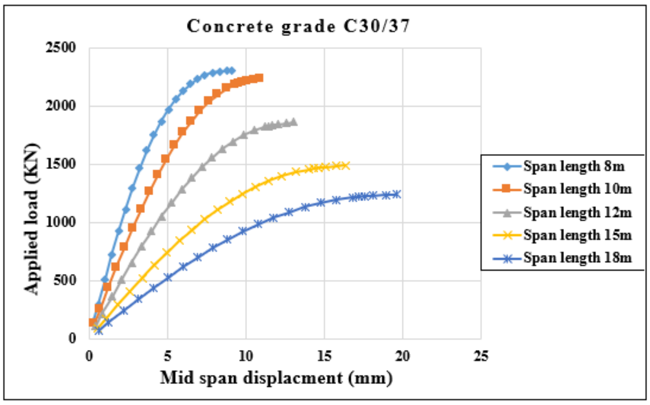


Figure 4.4 Load-displacement curve for C30/37 concrete grade

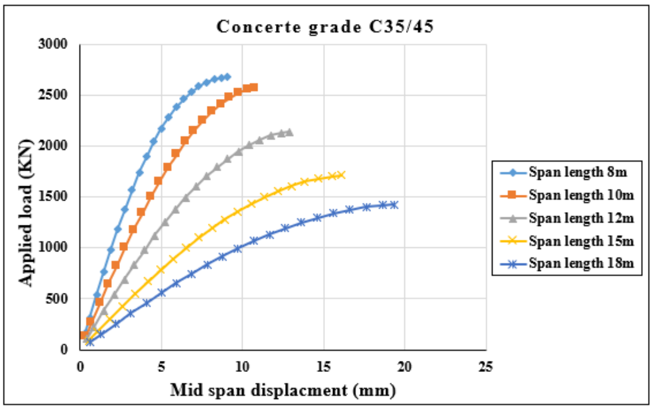


Figure 4.5 Load-displacement curve for C35/45 concrete grade

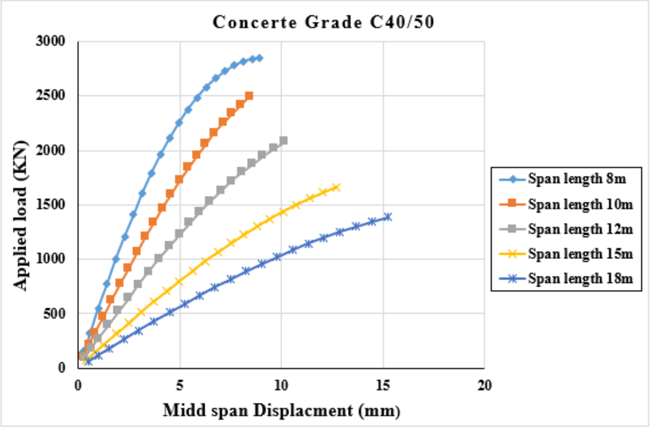
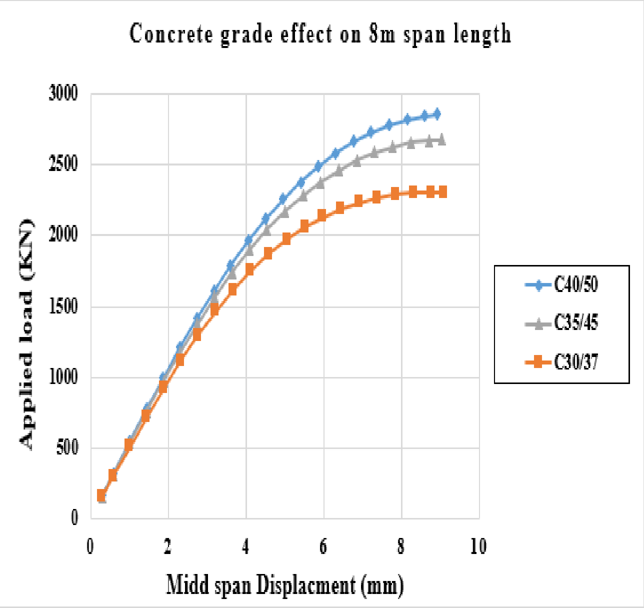


Figure 4.6 Load-displacement curve for C40/50 concrete grade



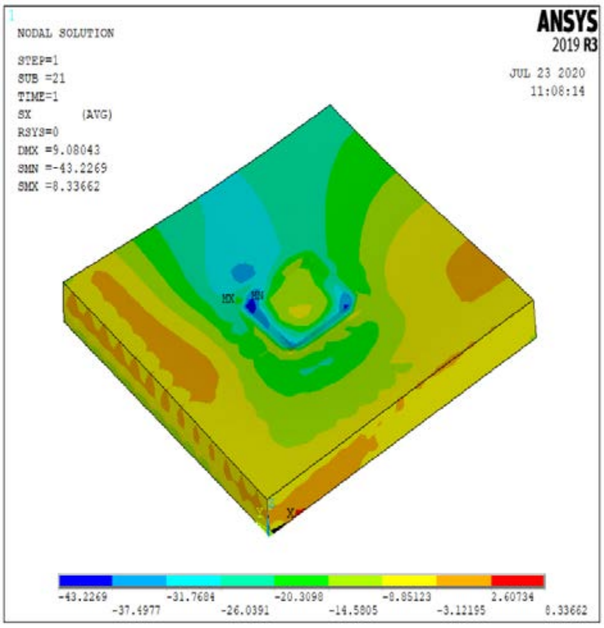


Figure 4.7 Load-displacement curve for 8m span of diffrnet concrete grade

Figure 4.8 a- stress in concrete (x-direction)

Table 4. 2 Failure load and maximum deflection of specimen with different concrete grade

	Specimen (ID)	**Concrete strength (Mpa)**	**Span length(m)**	**Tendons area (mm^2)**	**Slab thickness (mm)**	**Tendons position**	**Max. deflection (mm)**	**Failure load (KN)**
G4	PT1-6	C30/37	8	150	250	Bottom	-9.08	2301.69
	PT1-7		10				-10.88	2233.47
	PT1-8		12				-13.062	1861.23
	PT1-9		15				-16.33	1488.98
	PT1-10		18				-19.59	1240.82
G5	PT1-11	C35/45	8	150	250	Bottom	-9.022	2677.63
	PT1-12		10				-10.733	2568
	PT1-13		12				-12.88	2140
	PT1-14		15				-16.09	1712
	PT1-15		18				-19.32	1426.67
G6	PT1-16	C40/50	8	150	250	Bottom	-8.92	2853.49
	PT1-17		10				-8.96	2495.32
	PT1-18		12				-10.16	2079.43
	PT1-19		15				-12.69	1663.55
	PT1-20		18				-15.24	1386.29

4.3 Effect of Tendons area on load-displacement responses results

To study the effect of tendons area the parametric investigation conducted on fifteen models of the PT slab with tendons layout in one direction and spacing of the tendons 250mm with tendons area 150mm^2, 175mm^2, and 200mm^2 for span length 8m,10m,12m, 15m and 20m. the analysis results are discussed in the following subsection based on load deflection, stress intensity, and plastic strain results of ANSYS19.3.for tendons area 150 mm^2 effect on load - displacement responses resulted in failure load of 17365.2KN ,18072.8KN , 18441KN, 19093KN and 20186.12KN for span length 8m,10m,12m, 15m and 20m respectively it shows failure load increment of 3.9% ,2.0% ,3.4% and 5.4% with respect to increment of the span length of the specimen and corresponding displacement of 0.801mm, 1.297mm,1.766mm,3.043mm, and 4.24mm, at failure load.

for tendons area 175 mm^2 effect on load - displacement responses resulted in failure load of 17966.5KN ,18507.2KN , 18766.6KN, 18623.9KN and 19247.11KN for span length 8m,10m,12m, 15m and 20m respectively it shows failure load increment of 2.92% ,1.4% ,0.76% and 3.24% with respect to increment of the span length of the specimen and corresponding displacement of 0.922mm, 1.489mm,2.148mm,3.486mm, and 4.935mm, at failure load.

Tendons area 200 mm^2 effect on load - displacement responses resulted in failure load of 18182.9KN ,18453KN , 18252.4KN, 17377.6KN and 17150.7KN for span length 8m,10m,12m, 15m and 20m respectively it shows failure load increment of 2.92% ,1.4% ,0.76% and 3.24% with respect to increment of the span length of the specimen and corresponding displacement of 1.043mm, 1.677mm,2.415mm,3.921mm, and 5.545mm, at failure load.

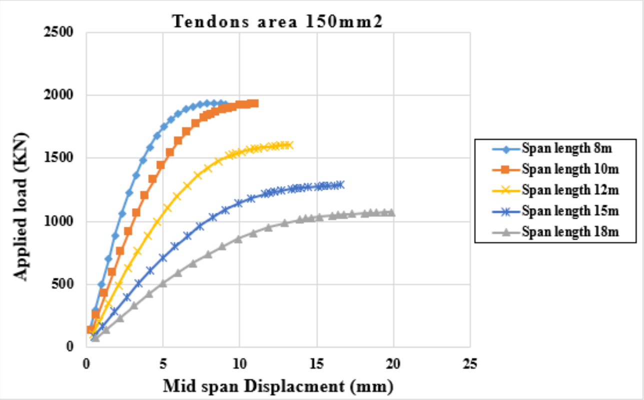


Figure 4.9 Load-displacement curve for tendons area of 150mm^2

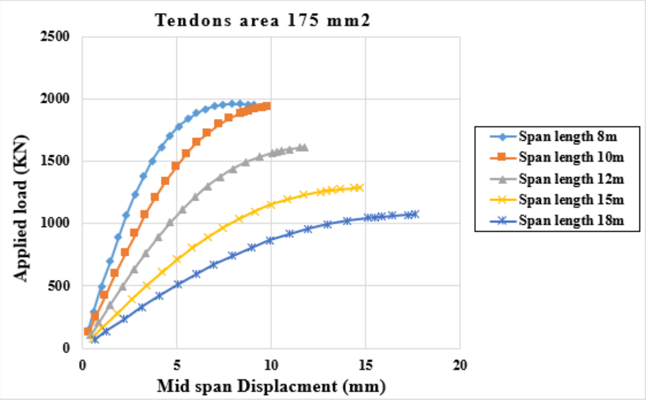


Figure 4.10 Load-displacement curve for tendons area 175mm^2

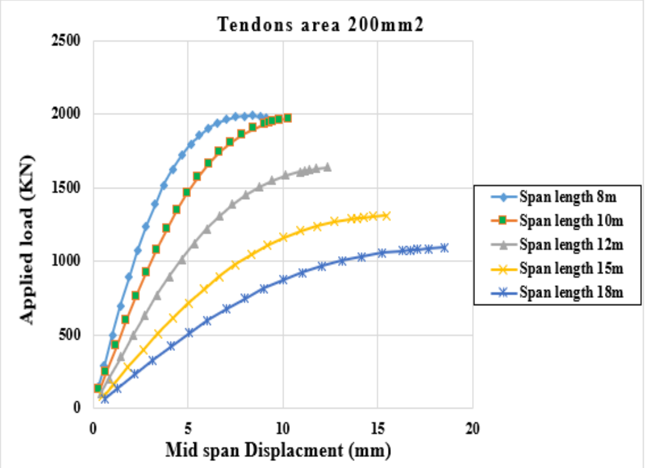


Figure 4.11 Load-displacement curve for tendons area 200mm^2

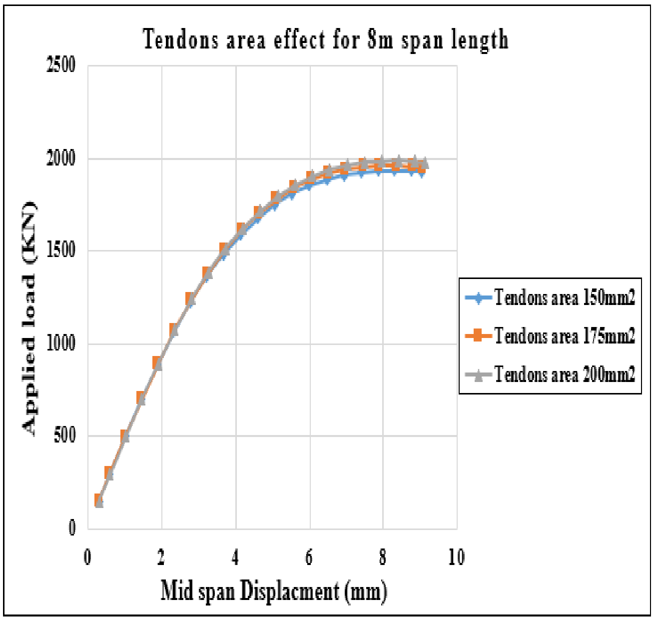


Figure 4.12 load-displacement curve for tendons area 200mm^2

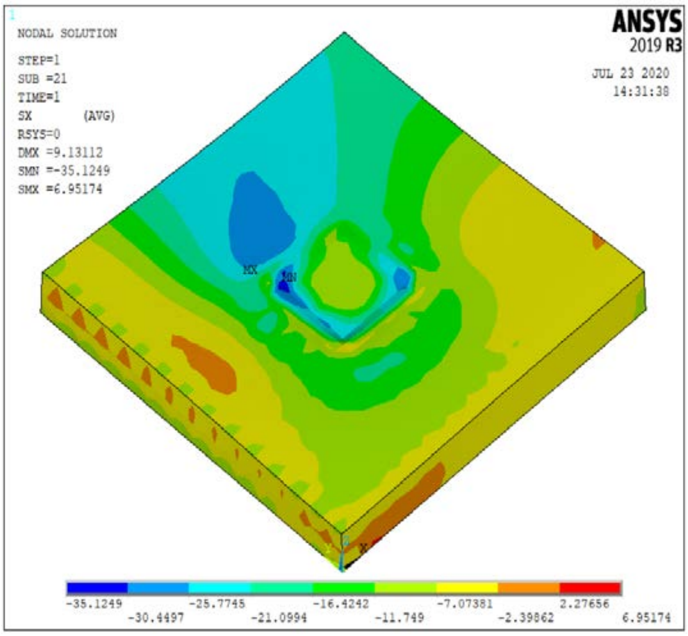


Figure 4.13 stress in concrete (x-direction)

Table 4. 3 Effect of tendons area on failure load of different span length of PT slab

	Specimen (ID)	**Tendons area(mm^2)**	**Span length(m)**	**Concrete strength (Mpa)**	**Slab thickness (mm)**	**Tendons position**	**Max. deflection (mm)**	**Failure load (KN)**
G7	PT1-21	150	8	C30/37	200	Bottom	-9.03	1930.82
	PT1-22		10				-11.04	1929.65
	PT1-23		12				-13.25	1608.04
	PT1-24		15				-16.56	1286.43
	PT1-25		18				-19.87	1072.03
G8	PT1-26	175	8	C30/37	200	Bottom	-9.08	1949.41
	PT1-27		10				-9.79	1933.78
	PT1-28		12				-11.75	1611.48
	PT1-29		15				-14.69	1289.19
	PT1-30		18				-17.63	1074.32
G9	PT1-31	200	8	C30/37	200	Bottom	-9.13	1975.75
	PT1-32		10				-10.294	1968.05
	PT1-33		12				-12.35	1640.04
	PT1-34		15				-15.441	1312.03
	PT1-35		18				-18.53	1093.36

5. Conclusion

The main objective of this study involves a detailed analytical investigation of the flexural behavior of long span PT concrete two-way slab with various unbonded tendon layout. Finite element package ANSYS program was used to model the long span PT concrete two-way slab. The accuracy of the numerical finite element analysis was verified by the comparisons with the onsite test load deflection results. The results obtained by using FE analysis were close to the onsite test results at time of the support were removed. To investigate the effect of tendons layout and span length on the overall behavior of longer span post-tensioned two-way concrete slab, various parametric study was conducted. sixty models were studied with different tendons layout, thickness of slab, tendons area, tendons position, concrete strength was studied under the parametric study. Failure loads, deflections, stress intensity, and plastic strain for all models and load versus deflection relationships were studied. The prestressing force was constant for all models, that was greatly affected the failure loads and deflections.

This research work numerically investigated flexural performance of post tensioned tow way concrete slab under flexural load Observed insights results From FEA are presented below.

- Finite element analysis results showed that the ultimate load capacity was highly affected by tendon layouts and area of the tendons. More specifically, the ultimate load capacity was increased due to using tendons in both directions of the slabs.
- The slab models with tendons in both directions showed a stiffer response and a higher ultimate load capacity compared to the slabs with tendons in one direction for all span length of PT slab specimen.
- The FEA Showed that the failure load in long span PT slab tendons layout in both directions increased about 7.5 % as compared with slab tendons in one direction.

- The parametric results showed that the ultimate load capacity was highly affected not only by tendon layouts but also the position of the tendons on the slab thickness. The ultimate load capacity was increased when tendons positioned at the bottom of the slabs. The failure load increased about 3.2 % as compared with tendons positioned at the middle and 0.6% when tendons positioned at the top of the slab thickness for constant tendons spacing of 400mm in one direction.
- FEA results shows slabs with one-direction tendons layout with C40/50 concrete grade for span length 8m showed 19.34% and 6.16% increase in the load caring capacity in comparison with the slabs with concrete grade of C30/37 and C35/45 respectively in one-direction tendons layouts. From this, it can be noted that using different concrete grade has effects in its ultimate load caring capacity of various long span PT slabs with tendons in both directions and one direction.
- The FEA analysis result shows tendons area has a strong effect on failure load of the PT slab as compare to other parameters, a various tendons area has used in one direction, 0.95% and 2.27% increase in the ultimate load capacity for span length 8m is observed for slabs with tendons area of 175mm^2 and 200mm^2 respectively in comparison with control specimen tendon area layouts.

Acknowledgements

I would like to express my deepest gratitude to my adviser

Dr. ing Nigatu Chaffo for their constant support and encouragement. afterwards, I would like to thank Dr. Tesfaye Alemu for his kindly assistance, encouragement and constructive ideas during the course of this research.

References

[1] Rafal Szydlowski and Barbara Labuzek "Post-Tensioned Concrete Long-Span Slabs in Projects of Modern Building Construction" (2017) IOP Conf. Ser.: Mater. Sci. Eng. 245 022065.

[2] Williams, M. S. and Waldron, P. "Movement of Unbonded Post -Tensioning Tendons during Demolition", Proceedings of the Institution of Civil Engineers (1989), Part 2, Vol. 87, pp. 225- 253. doi:10.1680/iicep.1989.2005.

[3] Yang, K. H., Mun, J. H. and Kim, G. H. "Flexural Behavior of Post -Tensioned Normal-Strength Lightweight Concrete OneWay Slabs", Engineering Structures (November 2013), 56, 1295-1307. Doi:10.1016/j.engstruct.2013.07.004.

[4] Ranzi, G., Al-Deen, S., Ambrogi, L. and Uym, B. "Long-Term Behaviour of Simply-Supported Post-Tensioned Composite Slabs", Journal of Constructional Steel Research (September 2013), 88, 172-180. Doi:10.1016/j.jcsr.2013.05.010

[5] Bailey, C. G. and Ellobody, E. "Fire Tests on Unbonded Post -Tensioned One-Way Concrete Slabs", Magazine of Concrete

Research(February2009),6,67-76.doi:10.1680/macr.2008.00005

[6] Thomas H.-K. Kang, Yu Huang, Myoungsu Shin, Ju Dong Lee, and Ah Sir Cho “Experimental and Numerical Assessment of Bonded and Unbonded Post-Tensioned Concrete Members” ACI structural journal Title No. 112-S60. **.**ACI S

[7] Abbas H. Mohammed, Nildem Taysi, Dia Eddin Nassani and Ali K. Hussein “Finite element analysis and optimization of bonded post-tensioned concrete slabs” DOI: 10.1080/23311916.2017.1341288.

[8] Nethravathi S.M, Darshan Prasad “Analysis and Comparative Study of Unbonded Post tensioned Cast-In-Place Parking Floor on the Effects of Tendon Layout using Safe“ ISSN: 2395-6992, Vol-3, Issue-7, July- 2017. S

[9] S. W. Han, S.-H. Kee, T. H.-K. Kang, S.-S. Ha, J. W. Wallace, and L-H. Lee “Cyclic behaviour of interior post-tensioned flat plate connections” Magazine of Concrete Research, 2006, 58, No. 00, Month, 1–13

[10] Mark Sarkisian pe, se, partner , Eric long pe, se, director ,Alessandro beghini pe, se, associate director,Rupa garai pe, se, associate director ,David shook pe, associate director ,Abel diaz pe, se, associate, Ricardo henoch pe , Skidmore, owings & merrill llp San francisco, ca. “New Methods in Efficient Post-Tensioned Slab Design Using Topology Optimization”, Conference Paper · April 2017, DOI: 10.1061/9780784480410.019

[11] Matthew J. Davey, “the performance of post-tensioned concrete wide band beams at exterior column connections under seismic loading,” Ph.D. Thesis, Swinburne University of Technology, Hawthorn, Victoria, Australia, July 2015.

[12] U. Prawatwong, C.H. Tandian and P. Warnitchai “seismic performance of post–tensioned interior slab-column connections with and without drop panel”, The 14 World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China Lecturer, Dept. of Engineering, Suranaree University of Technology, Thailand, Doctoral student, Dept. of Civil Engineering, the University of Tokyo, Japan, Assoc. Professor, School of Engineering and Technology, Asian Institute of Technology, Thailand.

[13] Shriraj S. Malvade, S.,“A Review on Seismic Assessment of Post Tensioned Flat Slab”. IJSTE - International Journal of Science Technology & Engineering (June 2016), Volume 2 , Issue 12 ,