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Parametric Study of Continous Composite Steel-Concrete Beam with External Prestressing

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ABSTRACT

In the present study three dimensional nonlinear finite element analyses were conducted to investigate the effect of several important parameters on behavior of external prestressed continuous composite steel-concrete beam. These parameters included the effects of concrete compressive strength, ratio of effective prestressing to ultimate stress (fpe/fpu), external prestressing technique, ratio of thickness to width of concrete slab (T/B), transfer load point to mid span section, type of loading, full and partial interaction, tendon profile, and number of stiffeners. It had been found that, at increasing the concrete compressive strength from (20 to 60MPa) and the ratio of prestress to ultimate stress from (0.264 to 0.79), the ultimate load was increased by about (19.64%) and (9.05), respectively. The ultimate load of continuous composite beam with external prestressing was increased by about (26.63%) than the same continuous beam without prestressing. The increase in the ultimate load of the continuous beam subjected to three point loads on each span was (25.93%) larger than that of the continuous beam with a single load on each span. It was noted that the ultimate capacity was increased by (7.32%) when draped tendon profile was used. Also it was noted that the ultimate load of beam with full interaction is (3.25%) greater than the same beam with partial interaction. Increasing the thickness to width of concrete slab ratio, from (0.1 to 0.25) with constant area of concrete, led to an increase in the ultimate load by about (6.60%). It was noted that the ultimate capacity increased by about (8.25%) when number of stiffeners were increased from three to seven.

Keywords: ANSYS program; parametric study; externally prestressed; continuous composite steel-concrete beams.

دراسة عوامل العتبات المستمرة المركبة من الحديد والخرسانة مع اجهاد مسبق خارجي

الخلاصة

التحليل اللاخطي الثلاثي الابعاد تم اجراءه باستخدام طريقة العناصر المحددة لبحث تأثير عدة عوامل مهمة على تصرف العتبات المستمرة المركبة من الحديد والخرسانة مع اجهاد مسبق خارجي. هذه العوامل تضمنت تأثير مقاومة الانضغاط للخرسانة، نسبة الاجهاد المسبق الفعال الى الاجهاد الاقصى، تقنية الاجهاد الخارجي المسبق, نسبة سمك الى عرض السقف الخرساني, انتقال القوة الى وسط مقطع العتبة, نوع التحميل، الترابط

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الجزئي او الكلي, شكل الوتر وعدد التقويات. وجد بزيادة مقاومة الانضغاط للخرسانة من (20 to 60 MPa) ونسبة الاجهاد المسبق الفعال الى الاجهاد الاقصى من (0.264 to 0.79) فان التحمل الاقصى سيزداد بمقدار (19.64%) و (8.05) على التوالي. التحمل الاقصى للعتبات المستمرة المركبة مع الاجهاد المسبق الخارجي اكثر بحدود (26.63%) من تحمل نفس العتبات المستمرة المركبة بدون اجهاد مسبق خارجي, وان الزيادة في التحمل الاقصى للعتبات المستمرة المعرضة لثلاث نقاط تحميل لكل فضاء هي (25.93%) اكثر من تحمل العتبات المستمرة المعرضة لنقطة تحميل واحدة لكل فضاء, ومن الملاحظ ايضا ان التحمل الاقصى يزداد بحدود (7.32%) عند استخدام الاوتار المثنية الشكل بدلا من الاوتار المستقيمة. وكذلك لوحظ ان التحمل الاقصى يزداد بحدود (3.25%) عند استخدام الترابط الكلي بدلا من الترابط الجزئي وبزيادة نسبة سمك الى عرض السقف الخرساني من (0.1 to 0.25) فان التحمل الاقصى سيزداد بحدود (6.60%) وان التحمل الاقصى يزداد بحدود (8.25%) عند زيادة عدد التقويات من ثلاثة الى سبعة مزدوجات.

الكلمات المرشدة: برنامج ANSYS،عوامل دراسية، العتبات المستمرة المركبة من الحديد والخرسانة مع اجهاد مسبق خارجي

INTRODUCTION

Externally prestressed structures, initially developed for bridges, are now becoming popular in bridge construction and strengthening or rehabilitation of existing structures [1]. Comparing with an internal prestressing system, an external prestressing system has some advantages, such as being simpler to construct and easier to inspect and maintain [2]. The external prestressing of the steel or composite beams is accomplished by means of high strength tendons anchored at the two ends of steel beam. The cable profile (straight or draped) is determined along the beam axis by a specific number of saddles at which the cable can slip [3]. Externally prestressing of steel or composite beams may be considered as a powerful economical alternative for strengthening the existing beams as well as for designing new beams. Composite beams strengthened with prestressed tendons display several failure modes [4]. These failure modes include (i) compression crushing of concrete (ii) yielding of steel beam web, (iii) interface shear failure (connection failure), and (iv) rupture of steel tendons. Out of these four failure modes, the fourth mode can be eliminated by providing special steel anchorages at the ends of and steel deviators along the tendons to eliminate stress concentrations. Shear or connection failure can be prevented by providing sufficient shear studs on the steel beam, to be encased in concrete. The other two failure modes, namely, compression crushing of concrete and yielding of steel beam is considered the imported factors in composite steel-concrete beams failure.

Literature Review

There are many achievements for the prestressing technique concerning both experimental and analytical can be found. Zong et al. [5] reported an experimental investigation of external prestressed steel-concrete composite continuous beams. One conventional non-prestressed and five prestressed two-span composite continuous beams. The results showed that the failures of the prestressed composite continuous beams were governed either by crushing of the concrete slab at the mid-span sections, or by local and distortional buckles at the internal support sections. Choi et al. [6] illustrated a systematic procedure of external post-tensioning technique for strengthening or rehabilitation of steel-concrete composite bridges based on the principle of virtual work. Nie et al. [7] proposed a general method for deformation analysis of prestressed continuous composite steel-concrete beams accounting for the slip effect between the steel and concrete interface under service loads. Chen et al. [8] investigated experimentally two groups of continuous steel-concrete composite beams (two-span and three-span). Each group consists of one non-prestressed composite beam and one prestressed composite beam with external tendons. Test investigations demonstrated that by prestressing with external tendons, the cracked moment resistance of a composite beam can be increased effectively; however, the yield moment in negative bending of the beam, as was expected, will not always increase. Also continuous composite box-girder bridge with prefabricated slabs investigated by other authors such as Hyung-Keun Ryu et al. [9], Chang-Su Shim et al. [10], and Qingtian Su et al. [11].

Significant Research

In this paper a finite element method using ANSYS computer program [12] is used to investigate the effect of several important parameters on the behavior of prestressed continuous composite steel-concrete beams. The prestressed continuous composite steel-concrete beam tested by Safan et al. [13] has been selected to carry out the parametric study.

General Description of Analysed Beam

As shown in Figure (1) the beam [13] is continuous composite beam, consisted of a concrete slab, steel beam, and two prestressing tendons. The steel beam had a total length of 14200mm, allowing 100mm of the beam length to extend beyond the end supports. The 600mm wide and 60mm thick concrete slab was compositely connected to the steel beam by means of shear stud connectors. Headed studs were welded to the steel beam top flange in a single row along the web axis. The connectors were symmetrically distributed with respect to the inner support section. Welding of connectors began at the end support sections and towards the inner support at a spacing of 400mm over a span length of 3600mm, after which the spacing was reduced to 200mm as shown in Figure (2-a). The studs had a total height of 54mm after welding and a shank diameter of 12.6mm. One layer of deformed steel bars was used to reinforce the concrete slab. The mesh consisted of 8Ø10mm uniformly distributed longitudinal bars and distributers of the same diameter at a spacing of 200mm transversally, as shown in Figure (2-b). Three pairs of 15mm thickness bearing stiffeners were welded to the steel beams one pairs at the inner supports and two at each mid-span. The steel beam was prestressed with two 15.5mm diameter continuous tendon running the full beams length between the two flanges.

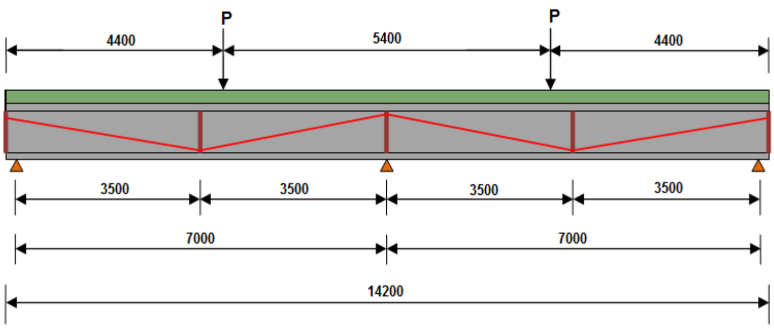
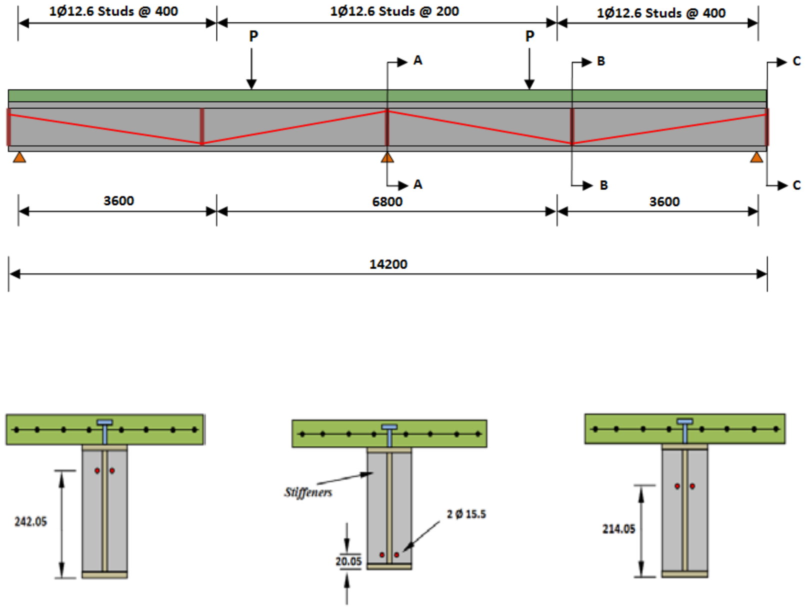
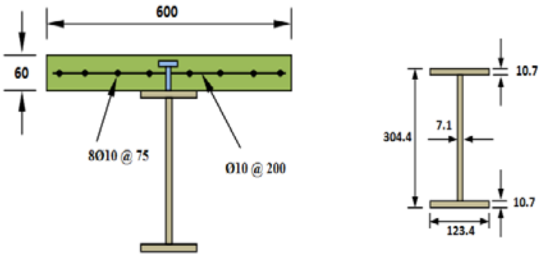


Figure (1) Loading configuration and dimensions of specimen [13]



Section (A-A) **Section (B-B)** **Section (C-C)**

(a) Shear connector's distribution



(b) Reinforcements details

Figure (2) Details of beam [13] (all dimension in mm)

Finite Element Model

The ANSYS computer program [12] was utilized for analyzing structural components encountered throughout the current study. Finite element representation and corresponding elements designation in ANSYS used in this study were discussed:

Element Model

SOLID 65 element type, as shown in Figure (3), had been used to model the concrete and its non-linearity for nonlinear analysis. It was used for 3-D modeling of solid with or without reinforcing bars .The solid element has eight nodes with three degrees of freedom at each node translations in the nodal x, y, and z directions. The element is capable of plastic deformation, cracking in three orthogonal directions, and crushing. SHELL 43 in ANSYS, as shown in Figure (3), was used to represent the steel beam in finite element, this element has 4-node with three translations in x, y and z in each node to achieve the compatibility condition with translation in x, y and z in adjacent solid element to it. The element has plasticity, creep, stress stiffening, large deflection, and large strain capabilities. To model steel reinforcement in finite element the discrete model LINK 8 was used in this study, as shown in Figure (4). LINK 8 is a spar (or truss) element. This element can be used to model trusses, sagging cables, links, springs, etc. The 3-D spar element is a uniaxial tension-compression element with three degrees of freedom at each node: translations of the nodes in x, y, and z-directions. No bending of the element was considered. Also LINK 8 was used to represent the external cable with initial strain for prestressing. Since the cable was located outside the steel section and the prestressing force is transferred to composite beam through end anchorages and stiffeners, the cable is connected to beam only at the anchorage or stiffeners. The solid element SOLID 45 was used for the steel plate's stiffeners. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions [14, 15]. A three-dimensional nonlinear surface-to-surface "contact-pair" element (CONTA-173 and TARGE 170), as shown in Figure (3), was used to model the nonlinear behavior of the interface surface between concrete and steel beam. A nonlinear spring element (COMBIN 39 in ANSYS) and (LINK 8), as shown in Figure (3), were used to represent the shear connector's behavior. COMBIN 39 is used to resist the normal force between the concrete and steel beam while LINK 8 works as stirrups in resisting the vertical shear at concrete layer. The models that have been considered have a number of parameters for each used element from element library in ANSYS for analogue representation of the tested beam; these parameters are summarized in Table (1).

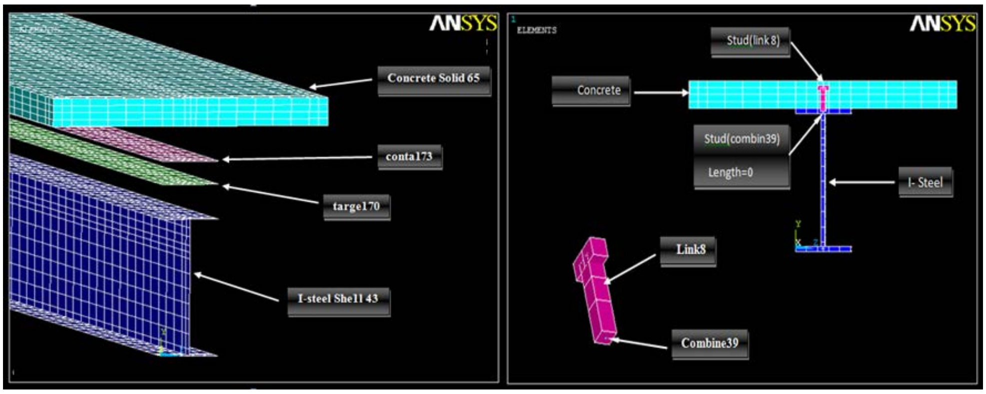
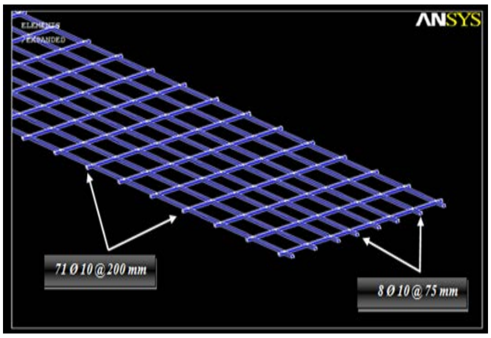


Figure (3) Element types



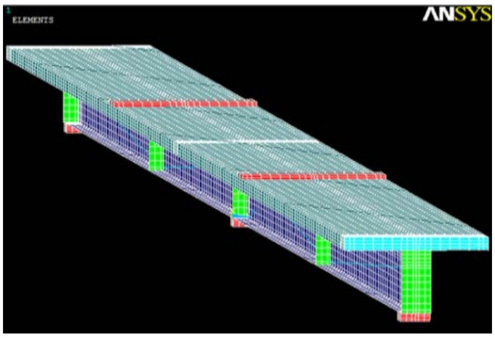


Figure (4) Reinforcement modeling **Figure (5) Mesh of beam**

Table (1) Model parameters for used elements in F.E. Model for beam

Concrete		**Steel Beam**		**External Prestrressing (Tendon)**	
Ultimate compressive strengt (MPa)	30	Yield strength (MPa)	300	Modulus of elasticity(MPa)	194540
Ultimate tensile strength (MPa)	3.0	Modulus of elasticity(MPa)	200000	Yield stress (MPa)	1673
Shear transfer parameters	0.6	Steel hardening (MPa)	6000	Effective prestress(MPa)	1497
	0.7	Poisson's ratio	0.3	Ultimate stress (MPa)	1894
Young's modulus (MPa)	25743			Area of external tendon(mm^2)	141.57
Poisson's ratio	0.2	**Reinforcement**		Steel hardening (MPa)	5836.2
Contact Surface		Modulus of elasticity(MPa)	200000	**Shear Connector**	
Coefficient of friction	0.7	Poisson's ratio	0.3	Ultimate dowel force (kN)	24766.56
Contact compatibility factor	1.0	Yield strength (MPa)	400	Coefficient of damping	0.0

Element Meshing of Beam

By taking advantage of the symmetry of both span's geometry and loading, one span of the entire model continuous beam is used for the finite element analysis cut from the inner support section. The aim of this was to reduce the computational time. After specifying the volumes and the areas, a F.E. analysis requires meshing of the model. In other words, the model was divided into a number of small elements, to obtain good results [16]. After meshing the beam the tendons were modeled, the use of a rectangular mesh was recommended. The width and length of elements in the interface surface was set to be consistent elements. The mesh used is shown in Figure (5), and the number of elements was shown in Table (2).

Table (2) Total number of elements for beam

Structural Component	Number of Elements
Concrete (Slab)	5920
I-STEEL (Beam and Stiffeners)	1992
Reinforcement (Longitudinal steel, Transverse steel, Tendon ,and Steel stud)	830
Shear Connectors (Combin39)	27
Solid 45 (Loading plate and Anchorages)	152
Interface (Shear Friction and Contact)	888

Displacement boundary conditions are needed to constrain the model to get a unique solution. The boundary conditions need to be applied at points of symmetry and where the supports and loadings exist. Since one span of continuous beam is taken in this model, one plane of symmetry is created. To model the symmetry, nodes on this plane must be constrained in the perpendicular direction on it, as shown in Figure (6).

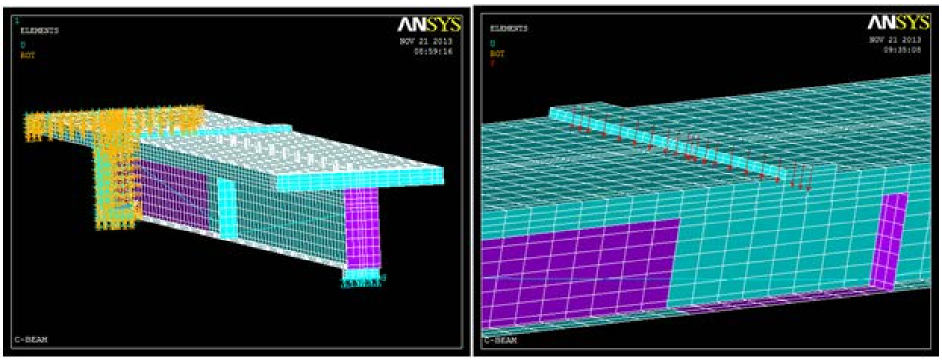
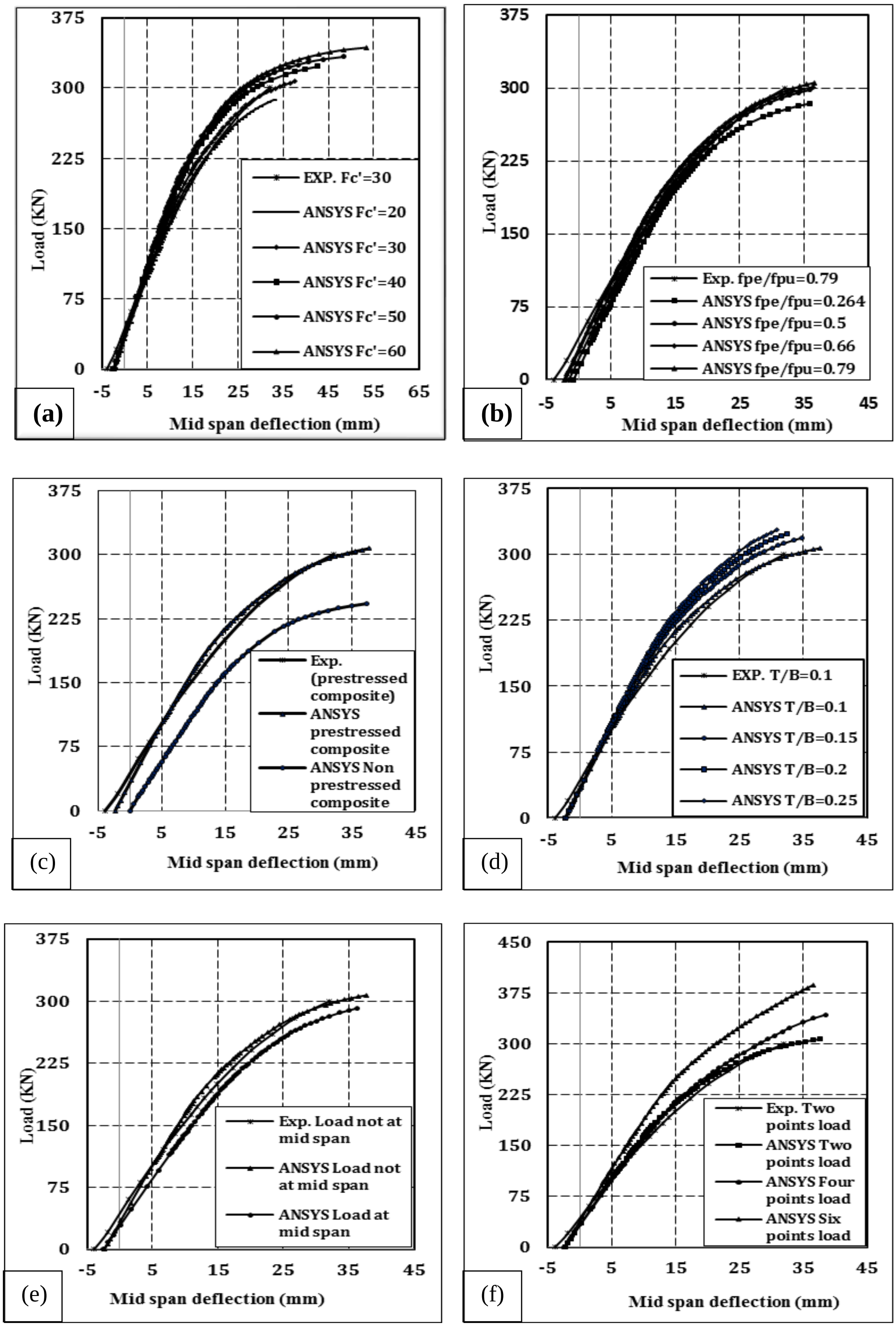


Figure (6) Loading and boundary conditions

Parametric Study

Effect of Concrete Compressive Strength

The beam [13] has been analyzed for different values of concrete compressive strength f'_c. These values were (20, 30, 40, 50, and 60)MPa. Figure (7-a) shows the effect of compressive strength of concrete slab on the load-deflection behavior of the selected beam. This figure indicates that the stiffness of continuous beam increases slightly with the increase of f'_c. Also it was clear that the maximum predicated deflection at mid-span is increase as the concrete compressive strength was increased. The numerical values of ultimate loads and deflections obtained for the different values of concrete compressive strength were listed in Table (3).


(a)
Load (KN)
Mid span deflection (mm)
EXP. Fc'=30
ANSYS Fc'=20
ANSYS Fc'=30
ANSYS Fc'=40
ANSYS Fc'=50
ANSYS Fc'=60
(b)
Load (KN)
Mid span deflection (mm)
Exp. fpe/fpu=0.79
ANSYS fpe/fpu=0.264
ANSYS fpe/fpu=0.5
ANSYS fpe/fpu=0.66
ANSYS fpe/fpu=0.79
(c)
Load (KN)
Mid span deflection (mm)
Exp. (prestressed composite)
ANSYS prestressed composite
ANSYS Non prestressed composite
(d)
Load (KN)
Mid span deflection (mm)
EXP. T/B=0.1
ANSYS T/B=0.1
ANSYS T/B=0.15
ANSYS T/B=0.2
ANSYS T/B=0.25
(e)
Load (KN)
Mid span deflection (mm)
Exp. Load not at mid span
ANSYS Load not at mid span
ANSYS Load at mid span
(f)
Load (KN)
Mid span deflection (mm)
Exp. Two points load
ANSYS Two points load
ANSYS Four points load
ANSYS Six points load

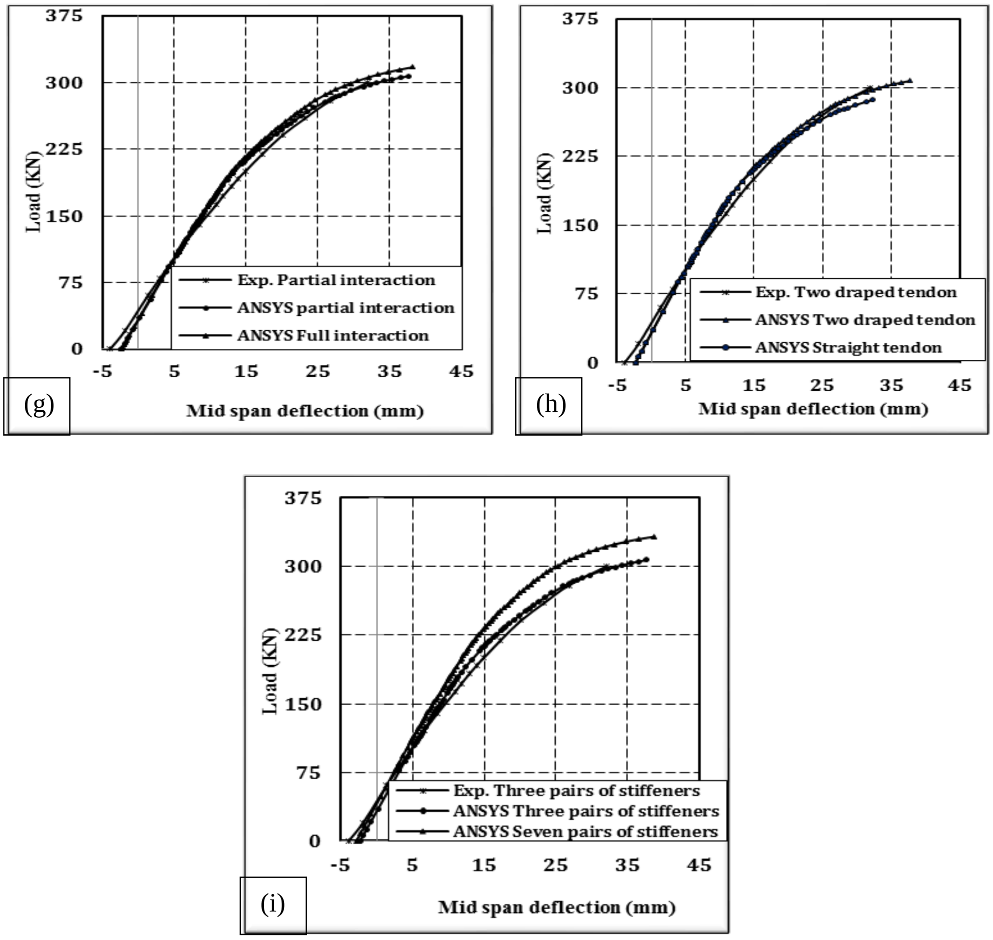


Figure (7) load-deflection curve

Table (3) Ultimate load and maximum deflection for different values of concrete compressive strength

Concrete compressive strength (MPa)	Ultimate loadat each span (kN)	Maximum deflection (mm)	% Change in ultimate load	% Change in maximum deflection
20*	286.94	32.69	0	0
30	307.23	37.7	7.07	15.3
40	322.98	42.54	12.56	30.13
50	333.48	48.38	16.22	47.99
60	343.29	53.43	19.64	63.44
Experimental (30)	300	32	-	-

*Reference beam

Ratio of Effective Prestressing Stress to Ultimate Tendon Strength (Fpe/Fpu)

The chosen values for ratio (fpe/fpu) were (0.264, 0.5, 0.66 and 0.79). Effect of prestressing stress on the load- deflection response of beam can be noted from Figure (7-b) and Table (4). These Figure and Table reveal that for higher values of (fpe), the ultimate load was slightly increased. This can be attributed to the effect of the external prestressing force that tends to prevent the cracks from extending and improves the stiffness.

Table (4) Ultimate load and max. deflection for different val. of (fpe/ fpu) ratio

Ratio (fpe/fpu)	**Ultimate load at each span (kN)**	**Max. def. (mm)**	**% Change in ultimate load**	**% Change in Max. def.**
0.264*	284.34	35.93	0	0
0.5	298.11	35.8	4.84	-0.36
0.66	301.26	36.31	5.95	1.06
0.79	307.23	37.7	8.05	4.93
Experimental (0.79)	300	32	-	-

*Reference beam

Effect of External Prestressing Technique

This section was compared the non-prestressed continuous composite beam results with the externally prestressed continuous composite beam results. Figure (7-c) shows the curves of load against mid-span deflection for each beam. A comparison of the load-deflection curves illustrates that the prestressed continuous beam deforms less than the non-prestressed continuous beam, or behaves more stiffly. Both beams behaved quite linearly in the load-deflection curves before yielding of the steel bottom flange for non prestressed continuous composite beam. The initial upward deflection had contributed to the lower deflection in the prestressed continuous composite beam, and the tangents of the curves of prestressed continuous composite beam are greater than those of the non-prestressed beam before yielding of the steel beam, they appear quite similar. The reason may be the incremental prestress in the tendons, which is small and develops linearly with the exerted load before the yielding of the steel beam in prestressed continuous composite beam, but increases much faster afterward. The results also demonstrate that adding prestressing to the continuous composite beams significantly increased the yield load and the ultimate strength. It was noted the ultimate load for external prestressed continuous composite beam is increased by 26.63% which was larger than that of non-prestressed continuous composite beam. Table (5) shows the ultimate load and maximum deflection values obtained from analysis.

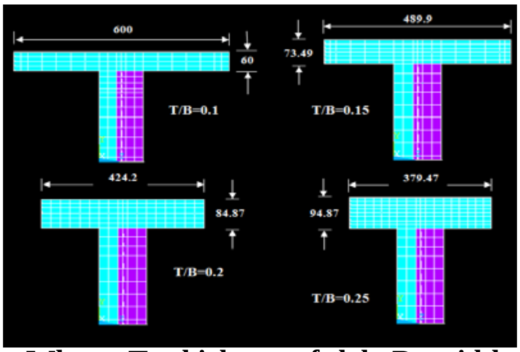
Table (5) Comparison between external prestressed composite and non-prestressed composite beam

Type of Beam	**Ultimate load at each span (kN)**	**Max. deflection(mm)**	**% Change in ultimate load**	**% Change in max.deflection**
Non prest. composite*	242.62	37.23	0	0
Prestressed composite	307.23	37.7	26.63	1.26
Exp.(prest. composite)	300	32	-	-

*Reference beam

Effect of Depth to Width of Concrete Slab Ratio

The effect of the ratio of concrete slab depth to its width (T/B) on the load-deflection behavior of prestressed continuous composite beams and their ultimate loads were studied in the present research. The selected ratios (T/B) were (0.1, 0.15, 0.2, and 0.25). In choosing these ratios in the F.E analysis, the total area of concrete slab was kept constant at (36000mm^2). Finite element mesh for all cases is illustrated in Figure (8). Figure (7-d) shows the effect of depth to width ratio on the load-deflection behavior of selected continuous beam. From this Figure, when the depth to width ratio increased, the ultimate load had been increased slightly. This is to be expected as an increase in thickness of slab would raise the neutral axis of the external prestressed continuous composite beam, hence increasing the eccentricity of tendon. The stiffness of continuous beam was increased by increasing the depth to width ratio of concrete slab. Also from Figure (7-d), it is clear that the maximum predicated deflection was decreased as the depth to width ratio of concrete slab was increased. Table (6) shows the ultimate load and deflection values obtained from analysis.



Where: T= thickness of slab, B= width of slab

Figure (8) F.E mesh of beam with different (T/B) ratio

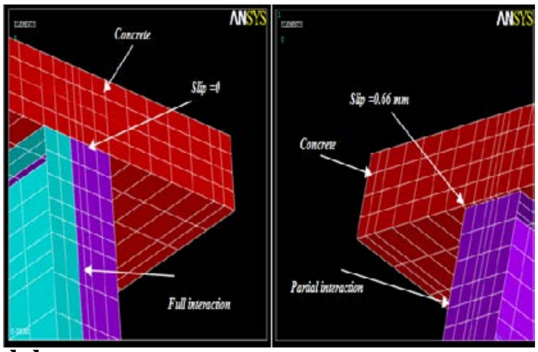


Figure (9) Numerical relative slip between concrete and steel for beam for full and partial interaction

Table (6) Ultimate load and maximum deflection for different values of concrete slab depth to width ratio

Depth to Width Ratio	Ultimate load at each span (kN)	Max. deflection(mm)	% Change in ultimate load	% Change in max. deflection
T/B = 0.1*	307.23	37.7	0	0
T/B = 0.15	318.74	34.86	3.75	-7.53
T/B = 0.20	323.53	32.54	5.31	-13.69
T/B = 0.25	327.52	30.82	6.60	-18.25
Exp. (T/B = 0.1)	300	32	-	-

*Reference beam

Effect of Load Point Location

This section was compared the loads point results at the mid span sections with continuous composite beam results which had a loads point applied at (800mm) from mid span section towards the inner support. Results were shown in Figure (7-e). The decreasing of load on the beam subjected to load point at mid span sections was 5.36% smaller than that in continuous beam with a single load not at mid span sections. Table (7) shows the ultimate load and deflection values obtained from analysis.

Table (7) Comparison between locations of loads

Type of Beam	**Ultimate Load at each span (kN)**	**Max. deflection(mm)**	**% Change in ultimate load**	**% Change in Max. deflection**
Load at mid span*	291.61	36.34	0	0
load not at mid span	307.23	37.7	5.36	3.74
Exp. (load not at mid span)	300	32	-	-

*Reference beam

Types of Loading

The effect of load application, on each span, on the load- deflection response was evaluated using three types of loading, namely, single concentrated load, two concentrated loads and three concentrated loads. Results are shown in Figure (7-f) and Table (8). The increasing of load on the continuous beam subjected to three point's loads on each span was 25.93% greater than that in continuous beam with a single point load on each span. This is because, during loading, cracks started to appear and spread as the load increased. This continued up to formation of the plastic hinge where the strain concentrated and stress increased up to failure.

Table (8) Ultimate load and maximum deflection for three types of loading

Type of loading	**Ultimate load Ateach span(kN)**	**Max.deflection (mm)**	**%Change in ultimate load**	**% Change in Max.deflection**
Single load on each span*	307.23	37.7	0	0
Two concentrated load on each span	343.31	38.58	11.74	2.33
Three concentrated load on each span	386.88	36.53	25.93	-3.10
Exp. Single load on each span	300	32	-	-

*Reference beam

Full and Partial Interaction

The present section focuses on the behavior of externally prestressed continuous composite beam with full and partial interaction using the finite element software ANSYS, the magnitude of full and partial interactions used were 1.4 and 0.8, respectively. The results of the analysis of prestressed continuous composite beams with full and partial interaction were presented in order to highlight the geometric nonlinear effects and how the ultimate loads were influenced by this effect. For continuous beam with full interaction analysis was found no slip between concrete slab and steel beam was occurred while for the same continuous beam with partial interaction (0.66mm) slip was recorded at interface surface as shown in Figure (9). The finite element results obtained for the same beam assuming full and partial shear interaction are shown in Figure (7-g). It can be noticed; a continuous composite beam with full shear interaction a stiffer behavior has been noticed. The ratio of the ultimate load obtained using a complete shear interaction to the partial interaction value was (1.032) as shown in Table (9).

Table (9) Ultimate loads and deflection for full and partial interaction of beam

Type of Interaction	**Ultimate load at each span (kN)**	**Max. deflection (mm)**	**% Change in ultimate load**	**% Change in Max. deflection**
Partial Interaction*	307.23	37.7	0	0
Full Interaction	317.22	38.28	3.25	1.54
Exp. Partial Interaction	300	32	_	-

*Reference beam

Influence of Tendon Profili

In this section two cases of external tendon profile were chosen to discuss the effect of tendon profile on the load - deflection response for externally prestressed continuous composite steel-concrete beam as shown in Figure (10), two draped tendon profile in first case and straight profile with in second case. Figure (7-h) shows the results of load-deflection response for two cases. It can be seen from this figure and Table (10), that the ultimate load capacity was increased with draped tendon profiles compared to undraped profiles (straight tendon profile) where was produced the lowest nominal resistance. While no change in stiffness before yielding. After yield point the draped tendon was stiffer and more ductile than straight tendon. The comparison between two cases of tendon profile in external prestressed continuous composite beams is shown in Table (10).

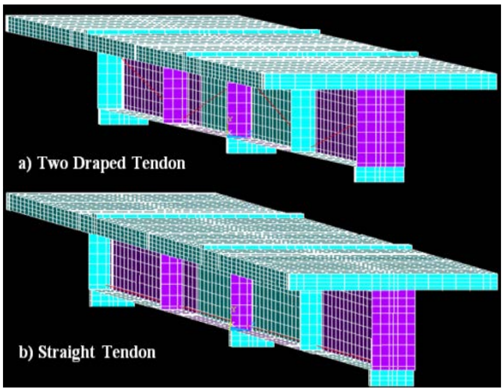


Figure (10) F.E mesh for two cases of tendon profile Figure

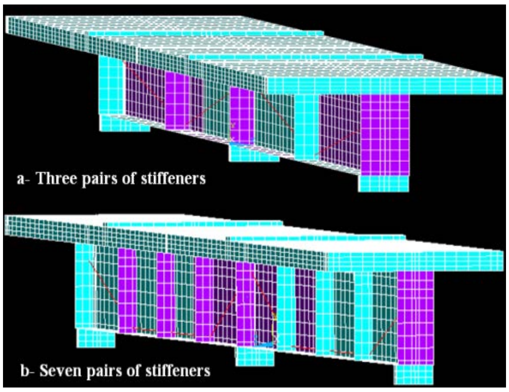


Figure (11) F.E mesh for two cases of stiffeners

Table (10) Ultimate load and deflection for two cases of tendon profile

Tendon profile	Ultimate load at each span (kN)	Max. def. (mm)	% Change in ultimate load	% Change in Max. def.
Straight tendon*	286.28	32.29	0	0
Two draped tendon	307.23	37.7	7.32	14.35
Exp.(Two draped tendon)	300	32	-	-

***Reference beam**

Effect of Number of Stiffeners

In order to study the influence of stiffeners on the response of externally prestressed composite steel-concrete beams, stiffener numbers was investigated for selected beam, where the selected beam had three pairs of stiffeners one under inner support and two under mid span section. The numbers was selected to study this effect are seven pairs of stiffeners as shown in Figure (11). The beam was subjected to one concentrated load in each span. Comparison between them on the behavior of load-deflection response was given in Figure (7-i). From this figure can be noted, difference in stiffness for beams after yield load and ultimate load. The numerical ultimate loads and the deflection obtained for the two cases are listed in Table (11).

Table (11) Ultimate load and deflection for different numbers of stiffeners

Number of stiffeners pairs	Ultimate load at each span (kN)	Max. def. (mm)	% Change in ultimate load	% Change in max. def.
Three pairs of stiffeners *	307.23	37.7	0	0
Seven pairs of stiffeners	332.6	38.64	8.26	2.49
Experimental (Three pairs)	300	32	-	-

*Reference beam

CONCLUTIONS

Depending on the numerical results, the following conclusions can be drawn:

1. The F.E.M used in the present work was able to simulate the behavior of prestressed continuous composite steel-concrete beams. The analytical tests carried out for the different cases studied indicated that the load-deflection response, ultimate loads were in good agreement with the experimental results.
2. From the numerical analysis carried out to study the effects of compressive strength of concrete and the effective prestressing stress ratio (fpe/fpu) on the strength behavior, it was found that as the compressive strength of concrete is increased from (20 to 60)MPa and the effective prestressing stress increased from (0.264 to 0.79) the ultimate load capacity was increased by about (19.64%) and (8.05%) respectively .
3. It was observed that the increase in the ultimate load capacity for external continuous prestressed beam by (26.63%) was larger than the same beam without external tendon.
4. The strength of continuous composite beams was increased by increasing the ratio of the depth to width of concrete slab (T/B), with keeping the total area of concrete slab constant and it was found that as the (T/B) ratio was increased from (0.1 to 0.25) the ultimate load increases by about (6.6%).
5. The strength of continuous composite beams was decreased by transfer load point to mid span section compared with load not at mid span section. It was (5.35%) smaller than that in continuous beam with a single load not at mid span sections.
6. The increased in ultimate load on the beam subjected to three points load on each span was (25.93%) greater than that in beam with a single load on each span.
7. The F.E results obtained for the same beam assuming full and partial shear interaction was shown that compared to a continuous composite beam with full shear interaction a stiffer behavior had been noticed. It was observed that the ultimate load capacity for beam with full interaction increase by (3.25%) was larger than the same beam with partial interaction.
8. It was found that the tendon profile had a clear effect on the ultimate load capacity. The ultimate load increased (7.32%) with two draped tendon profile compared to undraped profile.
9. Stiffeners web plate has a significantly effect on the behavior of externally prestressed continuous composite steel - concrete beams, where the results showed that when increased number of stiffeners to seven pairs of stiffeners the ultimate load increased by about (8.25%).

REFERENCES

[1].Amer M. Ibrahim, Saad k. Mohaisen, Qusay W. Ahmed "Finite Element Modeling of Composite Steel-Concrete Beams with External Prestressing", International Journal of Civil and Structural Engineering, Vol. 3, No. 1, 2012.

[2].Harajli M., Khairallah N., and Nassif H., “Externally Prestressed Members Evaluation of Second –Order Effects”. ASCE, Journal of Structural Engineering, Vol. 125, No 10, pp. 1151-1161, October, 1999.

[3].Davis S. W., “Investigation of the Flexural Strengthen of Concrete Beams using External Prestressing”. University of Southern Queensland, Faculty of Engineering and Surveying, pp. 78, October, 2005.

[4].Dabaon A., Sakr A., and Omnia Kh. " Ultimate Behavior of Externally Prestressed Composite Beams with Partial Shear Connection" Department of Structural Engineering , Ain Shams University , Egypt , May, 2005.

[5].Zong Z., Zheng Z., Fang Z., and Che. H. "Experimental Study of External Prestressed Steel-Concrete Composite Continuous Beams" China Journal of Highway and Transport, Vol.15, No.1, pp. 44-49, 2002.

[6].Choi D., Kim Y., and Yoo H., "External Post-tensioning of Composite Bridges by a Rating Equation Considering the Increment of a Tendon Force Due to Live Loads" Steel Structures 8, pp.109-118, 2008.

[7].Nie, J., Tao, M., Cai, C., and Li, S. "Deformation Analysis of Prestressed Continuous Steel-Concrete Composite Beams" J. Struct. Eng., Vol. 135, No. 11, PP. 1377–1389, 2009.

[8].Chen Sh., Wang X. , and Jia Y. " A comparative Study of Continuous Steel–Concrete Composite Beams Prestressed with External Tendons: Experimental Investigation " Journal of Constructional Steel Research, Vol. 65, No. 7, PP. 1480-1489, 2009.

[9].Hyung-Keun R., Chang-Su Sh., , Sung-Pil Ch., , and Chul-Hun Ch. "Inelastic Behavior of Externally Prestressed Continuous Composite Box-Girder Bridge with Prefabricated Slabs" Journal of Constructional Steel Research, Vol. 60, No. 7, July 2004, PP. 989–1005, 2004.

[10].Chang-Su Sh., Hyung-Keun R., Chul-Hun Ch., Seok-Goo Y., and Sung-Pil Ch. "Inelastic Behavior of a Continuous Composite Box-Girder Bridge with Prefabricated Slabs" Composite Construction in Steel and Concrete: pp. 57-66, 2006.

[11].Su Q., Yang, G., and Bradford, M., "Behavior of a Continuous Composite Box Girder with a Prefabricated Prestressed-Concrete Slab in Its Hogging-Moment Region" Journal Bridge Eng, 2014.

[12]."ANSYS Manual", Version (13.0).

[13].Safan M., and Kohoutkova A., "Experiments with Externally Prestressed Continuous Composite Girders". Acta Polytechnica, Vol. 41, No. 3, pp. 65-73, 2001.

[14].Ikbal N., Anas H., Qais A. and Husain M., "Behavior of Composite Steel-Concrete Beam Subjected To Negative Bending". Eng. and Tech. Journal. Vol. 27, No. 1, 2009.

[15].Ahmed F. Kadhum, "Nonlinear Behavior of Steel-Concrete Composite Beams Curved in Plane with CFRP Strips Bonding", Eng. and Tech. Journal. Vol. 28, No. 12, 2010.

[16].Anthony J. Wolansk, "Flexural Behavior of Reinforced and Prestressed Concrete Beams using Finite Element Analysis" MSc Thesis, Milwankee, Wisconsin, 2004.