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# Flexural performance of Prestressed tangible Bridges

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***Abstract*—The purpose of this study is firstly investigating numerically the research parameters to find the range of the structure parameters of the study then secondly asses experimentally the effects of the main design structural parameters on the flexural response of prestreeed Concrete Bridges. The analytical investigation consisted of using a commercial finite element analysis package (ANSYS, 2013) to predict deflections, strains, and stresses of five prestressed concrete beams subjected to monotonically increasing load up to failure. Then experimental parametric study was conducted for seven samples to examine the effect of affecting parameters which obtained from analytical analysis on the overall flexural response and ultimate load carrying.**

***Keywords*—prestressed concrete, flexural response, concrete bridge.**

## I. INTRODUCTION

A structure plays an important role in the development of an individual or state or country. Without high rise strong and aesthetic structures development of human race is unimaginable. A structure comprises of three major elements namely beam, column and slab. All these elements have importance of their own. Beams are one the most important structural member for any structures; it may be bridge, Industrial building, roadways etc. Pre-stressed concrete is a method for overcoming concrete natural weakness in tension. It can be used to produce beams, floors or bridges with a longer span than is practical with ordinary reinforced concrete. Pre-stressing tendons (generally of high tensile steel cable or rods) are used to provide a clamping load which produces a compressive stress that balances the tensile stress that the concrete compression member would otherwise experience due to a bending load. Traditional concretes based on the use of steel reinforcement bars, rebar, inside poured concrete. Pre-stressing can be accomplished in three ways: pre-tensioned concrete, and bonded or un-bonded post-tensioned concrete. It is a structural material possessing great strength.

## II. LITERATURE REVIEW

Yang et al., (2011) [1]**:** This study investigated the flexural behaviour of pre-stressed ultra high performance concrete (UHPC) beams is investigated in this study. The paper proposes a method for predicting the flexural strength of pre-stressed UHPC beams with a compressive strength greater than 150 MPa, including an experimental program and associated numerical analyses. Four large-scale pre-stressed beams were tested in the experimental program. Detailed experimental test results for the flexural behaviour of pre-stressed UHPC beams are provided. A method for incorporating steel fibre effects into the flexural analysis of pre-stressed UHPC beams is proposed and applied to interpret the experimental test results. The study focuses primarily on the flexural behaviour of UHPC beams. The analytical model for the flexural behaviour of beams takes tensile softening into account. Tensile softening is simulated using an inverse analysis based on the load-crack mouth opening displacement relationship. Test data and numerical analysis results for flexural strength are compared, indicating a reasonable agreement between beams. The present study allows realistic prediction of the flexural strength of prestressed UHPC beam.

Dall'Asta et al., (2007) [2]**:** This study proposed a Simplified Method for Failure Analysis of Concrete Beams Pre-stressed with External Tendons. The authors reported that the flexural strength of externally pre-stressed beams depends on the tendon stress at failure. If the tendon is free to slip at the deviators its stress will depend on the global deformation of the whole structure. Thus the tendon stress at failure, and consequently, the flexural strength cannot be evaluated by a local analysis of the critical sections, but a nonlinear analysis of the whole beam-tendon structural system is required. In the past, simplified formulas were proposed to calculate the tendon stress increment at failure avoiding the need for a nonlinear analysis of the entire structure. Some of these formulas have been adopted as code recommendations. Some approaches however do not seem to be consistent with the actual behavior of externally prestressed beams and in some cases excessively high increments of stress are recommended. On the other hand, other approaches appear to be too conservative. In this work a new simplified and rational method of analysis based on shape functions approximating deformations is proposed to study the tendon stress increment and consequently the flexural strength of externally pre-stressed concrete beams. The proposed simplified method reduces the analysis of externally pre-stressed structures from a global structure problem to an easier section problem.

Chee and Tan (2006) [3]: This study experimentally investigated the flexural behaviour of pre-stressed concrete beams. A total of nine simply supported prototype beams were tested to evaluate the effect of span-to-depth ratio and second-order effects. It was found that span-to-depth ratio has no significant effect on the flexural behaviour of the beams. For beams with span-to depth ratio of up to 22.5, a single deviator provided at midspan section is effective in minimizing second-order effects, that is, maintaining higher load-carrying capacity and ensuring ductility at the ultimate limit state for the beams. However, second-order effects prevailed in a longer beam with larger span-to-depth ratio of

30.0 despite the provision of a single deviator at midspan. This type of long beams would require at least two deviators placed at one-third span sections, hence reducing the deviator spacing in order to minimize second-order effects so that the beams would achieve the desired flexural performance with regard to beam strength and ductility. Theoretical predictions of the load–deformation responses using the proposed analytical model were found to agree well with the test results in this study and experimental data of other investigations.

Ghallab and Beeby (2005) [4]:This study investigated the effect of several factors on the increase in the ultimate stress in external Parafil ropes as well as external steel tendons. These factors were related to the external prestressing system, internal pre-stressed and ordinary bonded steel, beam geometry and material properties. Also, the accuracy of equations proposed by the Euro code (EC2), ACI318 and BS8110 to calculate the ultimate stress in external steel and FRP prestressing tendons was examined. The experimental and the analytical results showed that the studied factors have the same effect on both steel (up to yield) and Parafil ropes though this effect is greater in case of steel tendons. Also, factors such as tendon profile (straight or deviated), high strength of the concrete, effective tendon depth and number of deviators should be taken into consideration when calculating the ultimate stress in the external tendons.

Aravinthan et al.,(2005) [5]: This study searched the flexural behavior of beams with highly eccentric tendons, an experimental investigation is conducted on single-span and two-span continuous beams. The test variables include external tendon profile, loading pattern on each span, casting method, and confinement reinforcements. It is found that continuous girders with linearly transformed tendon profiles exhibit the same flexural behavior irrespective of tendon layout. The presence of confinement reinforcement enhances the ductility behavior but does not increase the ultimate flexural strength. The degree of moment redistribution is affected by the tendon layout and the loading pattern on each span.

## III. NONLINEAR FINITE ELEMENT ANALYSIS

This part presents the Finite Element Modeling. It includes a brief discussion of the chosen analysis program, history of using finite element method in non-linear analysis, main concept of this method for linear and nonlinear analysis, finite element and Range of applications in ANSYS, modeling of all elements which used in this study and finally investigating numerically to find the range of the structure parameters of this study.

### *Chosen analysis program*

In this study ANSYS finite element program is used. The concrete damaged plasticity model in ANSYS provides a general capability for modeling concrete in all types of structures using concepts of isotropic damaged elasticity in combination with isotropic tensile and compressive plasticity to represent the inelastic behavior of concrete.

### *Finite element method history*

The finite element method was introduced in the early 1950's by scientists like Argyris, Clough, Martin, Zienkiewicz . Since then the method has been developed to be one of the most powerful methods to solve engineering problems. Finite element method is based on matrix algebra and its efficiency depends directly on the performance of the computer. Nowadays, when powerful computers are available, new methods of non-linear analysis are being developed. The finite element method is today ,widely used especially in mechanical and civil engineering. There are vast amount of commercial finite element programs like ANSYS, ADINA, COSMOS, ABAQUS, PATRAN NASTRAN, DIANA and others.ANSYS version 13 was chosen in this thesis to study the behavior of prestressed concrete bridges with fiber tendons.

### *General Modeling Requirements*

The finite element method is an approximate technique, and as such, results computed using the finite element method must be critically evaluated before relied upon in a design application . This process of critical evaluation involves several steps for any structure being analyzed. The number of elements used in a model can greatly affect the accuracy of the solution. In general, as the number of elements, or the fineness of the mesh, is increased, the accuracy of the model increases as well as multiple models are created with an increasingly finer mesh, the results should converge to the correct numerical solution such that a significant increase in the number of elements produces an insignificant change in a particular response quantity.

Not all response quantities will converge at the same rate, however, displacements will generally be the most accurate response quantity computed and will converge faster than stresses, with the exception of some elements derived with hybrid stress formulations, in which case the stresses can converge at the same rate or higher than the displacements. Generally, however, convergence of displacements does not guarantee convergence of stresses since stresses are computed as derivatives of the displacement field. Furthermore, it may be necessary to increase the number of elements in areas of the model near either concentrated loads or boundary conditions, where the stress gradient is steeper.

Finally, once an engineer is confident that the numerical solution has converged and that the specific element chosen is appropriate for the current application, several other checks are necessary to validate the analysis. The sum of reactions of the model should be verified with hand calculations. The magnitude of global displacements should be checked and verified to be small with respect to the geometry of the structure. The equilibrium of the structure must be verified, as the finite element method does not guarantee that this important condition is satisfied. Once these criteria have been satisfied, it is important to determine if the results roughly follow the expected outcome. we must determine whether or not the results make physical sense . Contour plots of stresses and the displaced shape of the structure should roughly correspond to our intuitive sense. For example, symmetric results must accompany a structure with symmetric geometry and symmetric loading. Any deviation between expected and computed results must be critically investigated.

### *Range of Applications in ANSYS*

Applications of Finite Element in ANSYS divide into three categories, depending on the nature of the problem to be solved. The three categories are Steady state problems, Eigenvalue problems and Transient problems. Steady state problems are the most common problems used in finite element analysis. For an elastic problem in equilibrium the problem can be solved and its distortion calculated. From the displacements calculated the stresses and strains can be derived.

For thermal analysis, the temperature distribution and heat flow through a body can be calculated for a wide variety of boundary conditions .Eigen value problems are an expansion of the equilibrium problems. They involve the calculation of the fundamental characteristics of the system. These are steady state problems where the determination of natural frequencies and modes of vibration of solids and fluids are required .

Transient problems are composed of the problems of the first two categories with a time dimension added. The loads can be a function of time, and the finite element method is used to calculate the forced response of a body. The propagation of stress waves and transient heat flows form part of the transient problems . The range of possible applications of the finite element method extends to all engineering disciplines; however civil, mechanical and aerospace engineers are the most frequent users of the method.

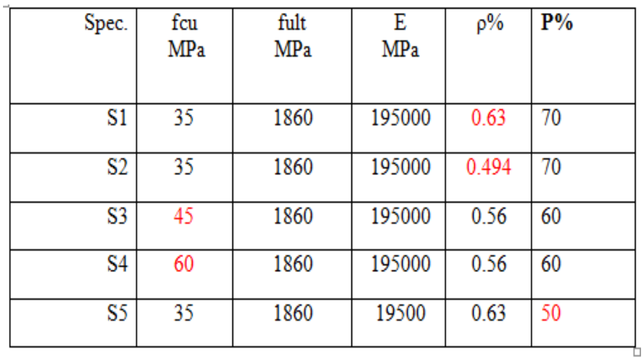
### *Finding numerically the range of the structure parameters of this study*

To investigate numerically to find the range of the structure parameters of this study five models with different properties are prepared and constructed by the use of ANSYS program, then results are compared .

### *Study Specimens*

* Models are strips with cross section and length (60cm * 30cm ) and 5m respectively ,Clear span in loading was 4.5 m, with shear span 175 cm ,concrete properties ,reinforcement details , reinforcement properties and level of prestressing for specimens are listed in table 1 .

**Table 1. Study specimens properties.**



| Spec. | fcu MPa | fult MPa | E MPa | ρ% | P% |
|---|---|---|---|---|---|
| S1 | 35 | 1860 | 195000 | 0.63 | 70 |
| S2 | 35 | 1860 | 195000 | 0.494 | 70 |
| S3 | 45 | 1860 | 195000 | 0.56 | 60 |
| S4 | 60 | 1860 | 195000 | 0.56 | 60 |
| S5 | 35 | 1860 | 19500 | 0.63 | 50 |

- Fcu : Concrete compressive strength .
- Fult : Ultimate tensile strength for prestressing tendons .
- E : Modulus of elasticity for prestressing tendons .
- ρ% : Prestressing reinforcement ratio.
- P% : Level of prestressing force .

### *Modeling*

Concrete was modeled with solid 65 solid elements , the steel bars were modeled using beam 188 elements , , the prestressing steel tendons were modeled using link 180 elements and loading plates were modeled with solid 185 solid elements .Concrete and loading plates were modeled as volumes.

### *Meshing*

To obtain good results from the volumes, the use of a rectangular mesh is recommended. Therefore, the mesh was set up such that square or rectangular elements were created .The volume sweep command was used to mesh concrete and the loading plates. This properly sets the width and length of elements in the plates to be consistent with the elements and nodes in the concrete portions of the model. The meshing of the reinforcement is a special case compared to the volumes. mesh of the reinforcement is needed with the same size of volume meshing which were created in the modeling However, the necessary mesh attributes as described above in models properties need to be set before each step of meshing.

### *Numbering Controls*

The command merge items merges separate entities that have the same location. These items will then be merged into single entities. Caution must be taken when merging entities in a model that has already been meshed because the order in which merging occurs is significant. Merging key points before nodes can result in some of the nodes becoming “orphaned”; that is, the nodes lose their association with the solid model. The orphaned nodes can cause certain operations (such as boundary condition transfers, surface load transfers, and so on) to fail. Care must be taken to always merge in the order that the entities appear. All precautions were taken to ensure that everything was merged in the proper order. Also, the lowest number was retained during merging.

### *Loads and Boundary Conditions*

Displacement boundary conditions are needed to constrain the model to get a unique solution. To ensure that the model acts the same way as the experimental model, boundary conditions need to be applied at supports and loadings exist. The supports were modeled As roller at first end and hinge at the other end . A single line of nodes in the roller case were given constraint in the UY direction applied as constant values of 0 , and A single line of nodes in the hinge case were given constraint in the UY direction ,UZ direction, and UX direction applied as constant values of 0. By doing this, the model will be allowed to rotate at the supports.

## IV. RESULTS

The goal of the comparison of the FE models is to ensure that the parameter chosen making an effective change in overall flexural behavior .

- Figure 1 shows Schematic of test set-up.
- Figure 2 shows deformed shape due to prestress loading only (camber upwards).
- Figure 3 shows deformed shape at final loading (at failure).
- Figure 4 shows cracks shape at final loading (at failure).

The following gives a brief description of resulted as presented in this stage:

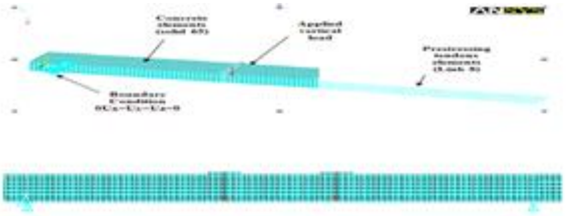


Figure 1 shows Schematic of test set-up

Figure 2 shows deformed shape due to prestress loading only (camber upwards).

Figure 3 shows deformed shape at final loading (at failure).

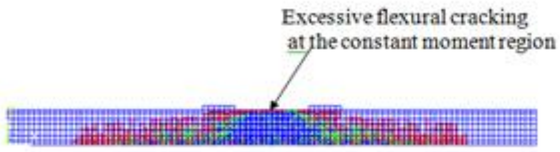


Figure 4 shows cracks shape at final loading (at failure).

***Load-deflection curves**

The load-deflection curves are presented in the form of x-y plot where the vertical axis represents the load in kN and the horizontal axis represents the corresponding deflection in mm.

*** Ductility ($\mu\Delta$)**

In general, displacement ductility factor is simply defined as the ratio of displacement value at ultimate load level (Δ u) to deflection value at end of elastic limit (Δ y).

*** Stiffness (Ks & KP)**

Two different stiffness slopes were named as secant stiffness (Ks), plastic stiffness (Kp). The initial slope (Ks) of the curve was determined as ratio of elastic limit load (Py) to summation of elastic limit deflection (Δ y) plus upward camber (Δ upward). The slope of the plastic stiffness (Kp) was determined as ratio of ultimate load (Pu) minus elastic limit load (Py) to ultimate deflection (Δ u) minus elastic limit deflection (Δ y).

*** Energy absorption index (E.A.I)**

The absorption index may be defined as the ratio of total area under load-deflection curve to area under elastic part at the same curve.

*** Over strength factor (Ω)**

Over strength factor is simply defined as the ratio of load value at ultimate load level (P u) to load value at end of elastic limit (P el).

***Effect of Prestressing Reinforcement Ratio***

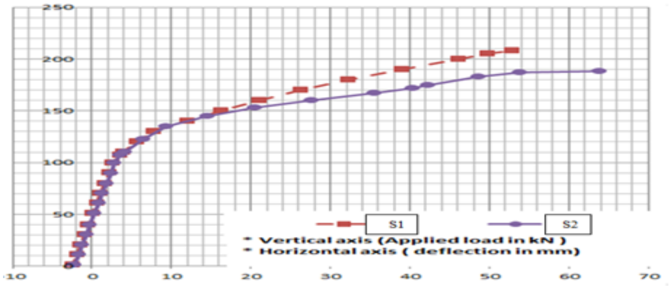


**Table 2. Effect of Prestressing Reinforcement Ratio**

| No. | ρ% | Ω | $\mu_\Delta$ | E.A.I | $K_i$ | $K_p$ | $K_p/K_i$ |
|---|---|---|---|---|---|---|---|
| S1 | 0.63 | 1.52 | 7.35 | 11.78 | 16124 | 1955 | 0.12 |
| S2 | 0.494 | 1.57 | 15.98 | 25.40 | 19048 | 1135 | 0.06 |

***Effect of concrete compressive strength***

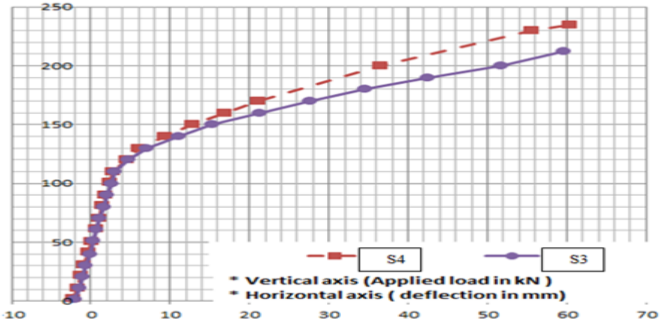


**Table 3. Effect of concrete compressive strength**

| No. | fcu MPa | Ω | $\mu_\Delta$ | E.A.I | $K_i$ | $K_p$ | $K_p/K_i$ |
|---|---|---|---|---|---|---|---|
| S3 | 45 | 1.77 | 14.90 | 39.45 | 30000 | 1654.7 | 0.06 |
| S4 | 60 | 1.92 | 8.55 | 18.36 | 14545 | 2240.3 | 0.15 |

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*Effect of level of prestressing*

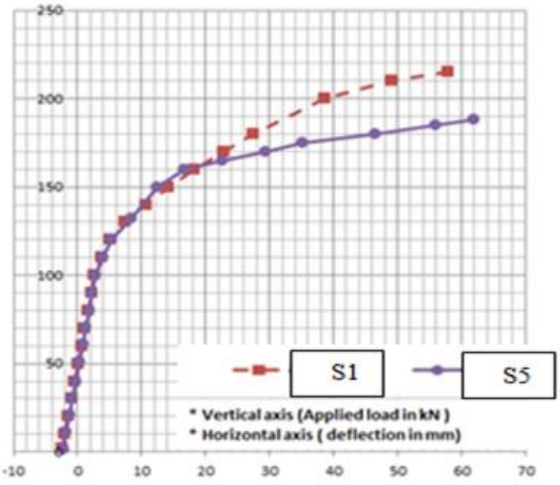

**Table 4. Effect of level of prestressing.**

| No. | P% | Ω | μΔ | E.A.I | $K_i$ | $K_p$ | $K_P/K_i$ |
|---|---|---|---|---|---|---|---|
| S1 | 70 | 1.52 | 7.35 | 11.78 | 16124 | 1955 | 0.12 |
| S5 | 50 | 1.90 | 10.70 | 9.95 | 15440 | 1584 | 0.10 |

The effects of key structural parameters chosen is effective on flexural behavior of prestressed concrete bridges with steel tendons, So in the next stage we will make experimental study for theses parameters with addition of eccentricity of cables and reinf. ratio of traditional steel.

## *PARAMETRIC EXPERIMENTAL STUDY*

The experimental program was consisted of testing seven prestressed concrete beams. All beams were rectangular in cross-section and nominally 2000 mm long, 120 mm width, 200 mm deep with a clear span (distance between supports) of 180 mm ( figure (5)).

All beams were reinforced with (2 * 10) upper, bottom reinf. and stirrups (8 * 6/m) .

All beams were post-tensioned with one strand with effective area equal 150 mm .

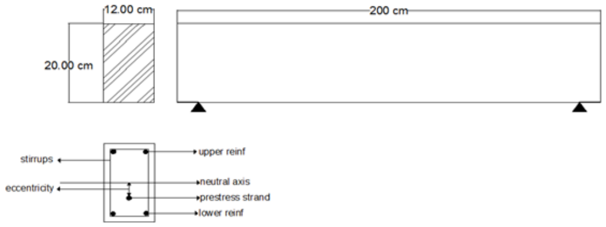

**Fig 5.Tested models**

Now,we had a brief introduction about the study parameters that had been taken in this study and how to display the results obtained.Second part dicuss the effect of changing cables eccentricity in flexural behavior with dicussion and analysis of the results.third part dicuss the effect of changing level of prestressing P% in flexural behavior with dicussion and analysis of the results. Third part dicuss the effect of changing concrete compressive strength fcu in flexural behavior with dicussion and analysis of the results.

In this parametric study we study three parameters which shown below:

- Effect of changing cables eccentricity.
- Effect of changing level of prestressing P%.
- Effect of changing concrete compressive strength fcu.

*Effect of Cables Eccentricity on The Flexural Behavior*

To study the effect of cables eccentricity (e) on flexural response and failure mode of the different models, three models with three different eccentricity values were studied experimentally, see table 4.Other parameters such as concrete compressive strength, model dimensions, level of prestressing, and ratio of steel (ρ) (ordinary & prestressing ) were constants for all tested models.

**Table 4: Models properties to study effect of changing eccentricity.**

| No. | e1 (mm) | e2 (mm) | P % | $f_{cu}$ (N/mm2) | $A_{ps}$ (mm2) | $A_s$ | $A_s'$ | $A_{stir.}$ /m | $M_{ur.}$ (Kn.m) | Type of prestressing |
|---|---|---|---|---|---|---|---|---|---|---|
| **B1** | 20 | - | 40 | 40 | 150 | 2 # 10 | 2 # 10 | 6 # 8 | 24.5 | partially |
| **B2** | 30 | - | 40 | 40 | 150 | 2 # 10 | 2 # 10 | 6 # 8 | 26.7 | partially |
| **B3** | 40 | - | 40 | 40 | 150 | 2 # 10 | 2 # 10 | 6 # 8 | 28.97 | partially |

**Table 5: Computed data at variable e**

| No. | e mm | $P_{cr}$ kN | $D_{cr}$ mm | $P_y$ kN | $D_y$ mm | $P_f$ kN | $D_f$ mm |
|---|---|---|---|---|---|---|---|
| B1 | 20 | 24 | 1.0 | 62 | 6.0 | 89.32 | 26.3 |
| B2 | 30 | 44 | 3.0 | 56 | 4.5 | 91.44 | 26 |
| B3 | 40 | 24 | 1.5 | 56 | 5.0 | 118 | 36 |

| No. | e mm | E.A. | μΔ | Ω | $K_S$ | $K_P$ | $K_P/K_S$ | Failure mode |
|---|---|---|---|---|---|---|---|---|
| **B1** | 20 | 1792.27 | 4.38 | 1.44 | 10.33 | 1.71 | 0.17 | Flexural tension |
| **B2** | 30 | 1909.33 | 5.77 | 1.63 | 12.44 | 1.82 | 0.15 | Flexural tension |
| **B3** | 40 | 4194.35 | 7.20 | 2.11 | 11.20 | 2.82 | 0.25 | Flexural tension |

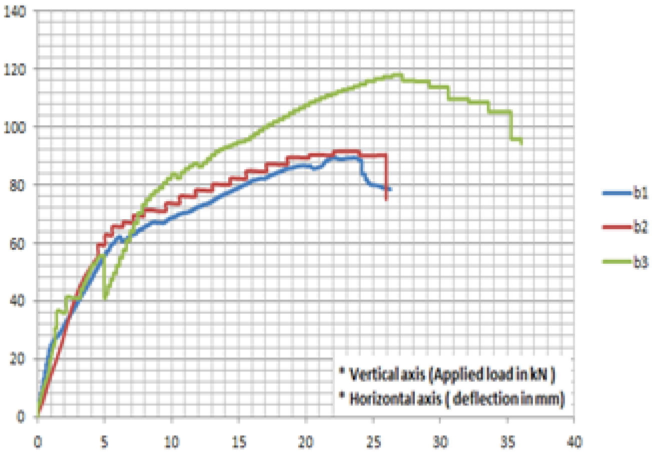

**Fig 6 load-deflection at variable e.**

The failure mode for these specimens was ductile failure , differs at location with changing value of eccentricity .this can be observed by increasing eccentricity value ,failure location extends horizontally to supports direstions with large crack width. Using of big eccentricity leads to significant improvement in flexural capacity with high ductility and deformability. Using of small eccentricity leads to low flexural capacity and deformability. It is observed that high eccentricity had the highest stiffness after cracking lost 75% of its stiffness after cracking. So, we can say that sample B3 had the best characteristics in both ultimate and serviceability stages with using high value of eccentricity.

### *Effect of Level of prestressing on The Flexural Behavior*

To study the effect of level of prestressing (P%) on flexural response and failure mode of the different models, three models with three different level of prestressing values were studied experimentally, see table 6.Other parameters such as concrete compressive strength, model dimensions, cables eccentricity, and ratio of steel (ρ) (ordinary & prestressing ) were constants for all tested models.

**Table 6: Models properties to study effect of changing level of prestressing**

| No. | e1 (mm) | e2 (mm) | P % | $f_{cu}$ (N/mm2) | $A_{ps}$ (mm2) | $A_s$ | $A_s'$ | $A_{stir.}$ /m | $M_{ur.}$ (Kn.m) | Type of prestressing |
|---|---|---|---|---|---|---|---|---|---|---|
| **B2** | 30 | - | 40 | 40 | 150 | 2 # 10 | 2 # 10 | 6 # 8 | 26.74 | partially |
| **B4** | 30 | - | 50 | 40 | 150 | 2 # 10 | 2 # 10 | 6 # 8 | 26.74 | partially |
| **B5** | 30 | - | 60 | 40 | 150 | 2 # 10 | 2 # 10 | 6 # 8 | 26.74 | partially |

**Table 7: Computed data at variable p%**

| No. | P % | $P_{cr}$ kN | $D_{cr}$ mm | $P_y$ kN | $D_y$ mm | $P_f$ kN | $D_f$ mm |
|---|---|---|---|---|---|---|---|
| **B2** | 40 | 44 | 3.0 | 56 | 4.5 | 91.44 | 26 |
| **B4** | 50 | 30 | 1.5 | 76 | 7.0 | 102 | 28.5 |
| **B5** | 60 | 50 | 2.0 | 90 | 5.0 | 112 | 29.5 |

| No. | P % | E.A. | μΔ | Ω | $K_S$ | $K_P$ | $K_P/K_S$ | Failure mode |
|---|---|---|---|---|---|---|---|---|
| **B2** | 40 | 1909.33 | 5.77 | 1.63 | 12.44 | 1.82 | 0.15 | Flexural tension |
| **B4** | 50 | 2243.28 | 5.83 | 1.34 | 11.85 | 1.73 | 0.16 | Flexural tension |
| **B5** | 60 | 2767.00 | 5.9 | 1.24 | 18.00 | 1.83 | 0.10 | Flexural compression |

The failure mode for these specimens was flexural, differs at location with changing prestressing force. Failure location change from tension at tendons to compression at concrete by increasing prestressing force. Using of high prestressing force (60%) leads to significant improvement in flexural capacity with compression failure probably due to appearance of small hair cracks after stressing that reduce gross area of the compression zone which make this type of failure in this case. Using of prestressing force (50%) leads to ductile failure with alarming by large crack width ,had high load capacity compared with B5,B2 and had the highest stiffness after cracking . So, we can say that sample B4 had the best characteristics in both ultimate and serviceability stages with using P% = (50%) , sample B4 is the best second one which had good failure mode with medium load capacity and sample B5 had rejected failure mode.

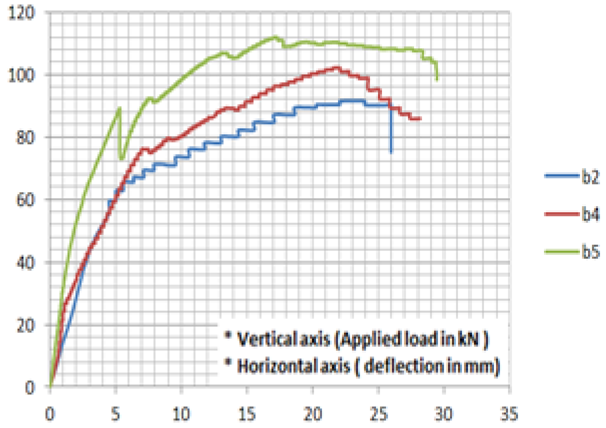

**Fig 7. load-deflection at variable p%**

### *Effect of Concrete Compressive Strength on The Flexural Behavior*

To study the effect of concrete compressive strength (fcu) on flexural response and failure mode of the different models, three models with three different concrete compressive strength values were studied experimentally, see table 7.Other parameters such as level of prestressing , model dimensions, cables eccentricity, and ratio of steel (ρ) (ordinary & prestressing ) were constants for all tested models.

**Table 8: Models properties to study effect of changing concrete compressive strength.**

| No. | e1 (mm) | e2 (mm) | P % | $f_{cu}$ (N/mm2) | $A_{ps}$ (mm2) | $A_s$ | $A_s'$ | $A_{stir.}$ /m | $M_{ur.}$ (Kn.m) | Type of prestressing |
|---|---|---|---|---|---|---|---|---|---|---|
| **B6** | 30 | - | 40 | 30 | 150 | 2 # 10 | 2 # 10 | 6 # 8 | 22.70 | partially |
| **B2** | 30 | - | 40 | 40 | 150 | 2 # 10 | 2 # 10 | 6 # 8 | 26.74 | partially |
| **B7** | 30 | - | 40 | 50 | 150 | 2 # 10 | 2 # 10 | 6 # 8 | 29.18 | partially |

**Table 9. Computed data at variable concrete compressive strength.**

| No. | $f_{cu}$ (N/mm$^2$) | $P_{cr}$ kN | $D_{cr}$ mm | $P_y$ kN | $D_y$ mm | $P_f$ kN | $D_f$ mm |
|---|---|---|---|---|---|---|---|
| **B6** | 30 | 42 | 4.5 | 64 | 5.0 | 78.00 | 27 |
| **B2** | 40 | 44 | 3.0 | 56 | 4.5 | 91.44 | 26 |
| **B7** | 50 | 44 | 2.0 | 112 | 5.5 | 144 | 33 |

| No. | $f_{cu}$ (N/mm$^2$) | E.A. | μΔ | Ω | $K_S$ | $K_P$ | $K_P/K_S$ | Failure mode |
|---|---|---|---|---|---|---|---|---|
| **B6** | 30 | 1543.60 | 5.40 | 1.22 | 4.92 | 1.40 | 0.28 | Flexural compression |
| **B2** | 40 | 1909.33 | 5.77 | 1.63 | 12.44 | 1.82 | 0.15 | Flexural tension |
| **B7** | 50 | 3688 | 6.00 | 1.29 | 12.44 | 1.68 | 0.14 | Flexural tension |

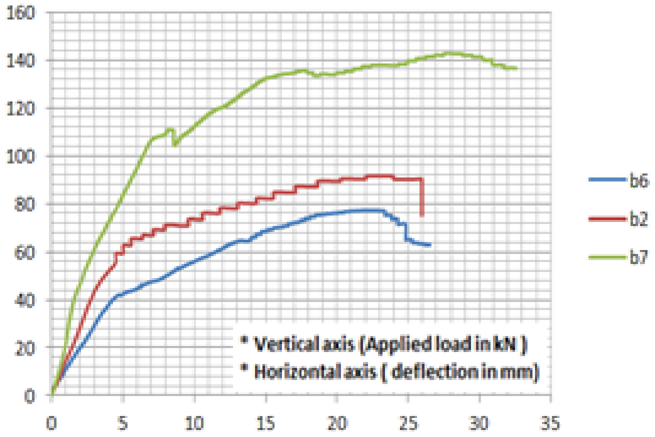

**Fig 8. load-deflection at variable Fcu.**

The failure mode for these specimens was flexural failure , differs at location with changing concrete compressive strength . Failure location change from compression at concrete to tension at tendons by increasing concrete compressive strength. Using of high concrete compressive strength (50 N/mm2) leads to significant improvement in flexural capacity with high ductility and deformability. Using of concrete compressive strength =30-40 N/mm2 leads to low improvement in the ductility , deformability and flexural capacity . Lowest fcu sample B6 had the highest stiffness after cracking lost 70% of its stiffness after cracking but had rejected compression failure mode. So, we can say that sample B7 had the best characteristics in both ultimate and serviceability stages with using Fcu = (50 N/mm2).

## V. CONCLUSION

The purpose of this study is firstly investigating numerically the research parameters to find the range of the structure parameters of the study then secondly asses experimentally the effects of the main design structural parameters on the flexural response of prestressed Concrete Bridges..

The analytical investigation consisted of using a commercial finite element analysis package (ANSYS, 2013) to predict deflections, strains, and stresses of five prestressed concrete beams subjected to monotonically increasing load up to failure. Then experimental parametric study was conducted for fourteen samples to examine the effect of affecting parameters which obtained from analytical analysis on the overall flexural response and ultimate load carrying. recommended an increase of studies in this field to enhance design guide lines in all codes whereas; their properties and behavior have not been fully explored. The research presented in this thesis can be concluded below:

The effects of key structural parameters on flexural behavior of prestressed concrete bridges with steel tendons. Firstly, the effect of changing cables eccentricity, secondly, the effect of changing level of prestressing P% in flexural behavior , thirdly the effect of changing concrete compressive strength .

The following major conclusions can be drawn from this study:

1- The flexural prestressing reinforcement ratio ρ, concrete compressive strength fcu, cables eccentricity, type of prestressing, non-prestressing steel reinforcement ratio and initial prestressing force P% affects the flexural behavior, ultimate load, and failure modes of the concrete beam models.

2- The increase of vertical eccentricity to 40% of depth increases load carrying capacity by 33% and 29% compared with vertical eccentricity equal 20% and 30% of all depth respectively.

3- The increase of vertical eccentricity to 40% of depth doubled toughness compared with samples that eccentricity equal 20% and 30% of all depth.

4- High eccentricity sample had the highest stiffness after cracking.

5- The increase of flexural prestressing reinforcement ratio for all samples increases load carrying capacity. Because tension prestressing reinforcement plays vital role in reducing crack width and prevent crack from developing at low load levels.

6- A greater level of total prestressing force reduce the cracking ,as it reduces the number and size of cracks that develop under loading, and increases load capacity and toughness.

7- Using level of prestressing equal 60% had a compression failure mode due to appearance of small top hair cracks immediately after stressing which decreases gross compression area until loading.

8- - For all samples and for a fixed value of prestressing force level and prestressing reinforcement ratio, the higher the concrete compressive strength the higher load-carrying capacity.

9- - For (30&40&50 MPa) concrete compressive strengths to achieve high strength & ductility & high yielding load we should use concrete compressive strength equal 50 MPa.

10- Lowest fcu sample 30 MPa had the highest stiffness after cracking lost 70% of its stiffness after cracking but had rejected compression failure mode.

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