International Journal on Emerging Technologies **11**(2): 420-426(2020)

ISSN No. (Print): 0975-8364
ISSN No. (Online): 2249-3255

Optimization in the Design of Prestressed Concrete Girders using Excel and MATLAB

Tensing D.[1]***, Vincent Sam Jebadurai S.***[2]***, Joe Paulson***[2]***, Rahul A.V.***[3] ***and Kevin Jefrey***[3]
[1]Professor, Department of Civil Engineering, Karunya Institute of technology and Sciences (Tamil Nadu), India.
[2]Assistant Professor, Department of Civil Engineering,
Karunya Institute of Technology and Sciences, Coimbatore (Tamil Nadu), India.
[3]PG Students, Department of Civil Engineering,
Karunya Institute of technology and Sciences, Coimbatore (Tamil Nadu), India.

(Corresponding author: Vincent Sam Jebadurai S.)
(Received 26 December 2019, Revised 17 February 2020, Accepted 19 February 2020)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT - An analytical study was made on optimizing the design of prestressed concrete flanged beams using Microsoft Excel and MATLAB program for different spans and live loads. The military engineering handbook for the design of prestressed concrete flanged beams recommends guidelines for arriving at preliminary dimensions of the flanged sections based on M_D/M_L ratio of an equivalent rectangular section. In this investigation, studies have been made on the spans such as 15m, 20m, 25m and 30m for varying live loads of 15kN/m, 20kN/m, 25kN/m and 30kN/m to obtain suitable cross sections using MS excel as well as MATLAB program. The arrived sections were checked for stresses. In all the cases of study, the stress at the bottom fibre at transfer was found as higher in the first trial. Hence the sections were modified by increasing the bottom flange area alone and best sections could be arrived. The factor of safety values were obtained as per the limit state of collapse. The factor of safety of the sections were worked out to be in the lowest possible range of 1.5 to 1.60. However, for larger spans the factor of safety could not be restricted with the above range. The concept was applied for a smaller span of 10rm and was found that instead of flanged sections rectangular sections can be preferred. This paper presents the M_D/M_L ratios and the appropriate optimum dimensions for the final prestressed concrete flanged sections for the varying loads and spans.

Keywords: Bending moment,Eccentricity of cables, Factor of safety, Freyssinet cables, Live load,MD/ML Ratio.

NOMENCLATURE

H	Depth of the equivalent rectangular section	b_{tf}	Width of top flange
M_D	Dead load bending moment	b_{bf}	Width of bottom flange
M_L	Live load bending moment	FA	Firefly algorithm
P_i	Prestressing force	BSA	Backtracking search Algorithm
e	Eccentricity	ICA	Imperialist Competitive algorithm
Y_1,Y_2	Depth of Neutral axis from top and bottom	GA	Genetic Algorithm
FoS	Factor of Safety		

I. INTRODUCTION

Prestressed concrete is advantageous due to its higher moment carrying capacity and enhanced resistance for deformation. Apart from this, Prestress concrete is favoured because it remains uncracked, with an improved durability, high span-to-depth ratio, less dead load and more cost-effective. There are two basic ways to apply pre-stress to a structural member. The first is often used in factory situations known as pre-tensioning. Always for the construction at the site, post-tensioning is preferred. Post tensioning is being done for most of the bridges in the National Highways in India in the present days.

The design of prestressed concrete beams were in practice since the late nineteenth century. Many methods of design had been developed during the entire twentieth Century. Existing methods of design of prestressed concrete beams/ girders is cumbersome which results mostly in uneconomical sections. Hence it is necessary to study the possibility of arriving at economical sections using the existing theoritical concepts. A detailed study on the existing literature is made in this regard and suitable solution for getting an economical section using the concepts of Military Engineering Handbook for the design of prestressed concrete is presented in this paper.

Bhawar *et al.*, (2015) took up a specific problem and considered the cost minimization variables of the bridge system as girder width, cross-sectional girder dimensions and the number of tendons [1].

A program for the analysis and design of low-cost pre-stressed girders has been developed in the MATLAB R2010 software.They found that the overall cost of the structure reduces by using an optimization technique with stability. (Here, in this study cost optimization has done by minimizing the design in I-girder but left the optimization in the design of girders with different spans subjected to different loads. Our study fills the gap in this area by considering Md/Ml ratios through excel and matlab calculations and determines the suitable cross-section for different spans).

Aydın and Ayvaz (2010) explored the optimal topology and design of pre-stressed concrete bridge girders using a genetic algorithm [2]. These included structural variables such as cross-section dimensions area of pre-stressed steel and number of bridge beams, displacement and geometric constraints for optimal construction. They found that results obtained by the proposed GA-software are up to 28% more economical than the real-life project. (Here, in this study cost optimization has done by using genetic algorithm driven software without violating design constraints in the design of prestressed girder but left the optimization in suitable spans subjected to different loads. Our study fills the void in this area by considering Md/Ml ratios through excel and MATLAB calculations and determines the suitable cross- sections).

Quaranta *et al.*, [3]; Ma *et al.*, (2019) [4] discussed Optimum design of pre-stressed concrete beams using a special (μ + λ)-constrained differential evolution algorithm to solve the optimization problem.

From the numerical results and comparisons with various soft computing approaches inspired by nature (genetic algorithms and particle swarm optimization algorithms), they concluded that swarm intelligences based optimizers provide a final design solution that is cheaper than that measured using genetic algorithms. This study lags behind in the design optimization by not considering suitable cross-sections of different spans subjected to different loads. Our study fills the gap in this area).

Chen *et al.* (2019) developed an optimal design method, as well as discovering the optimum combination of PT tendons and shear connectors while maintaining the moment efficiency of the wall equal to the design moment applied and at the same time achieving zero residual drift [5].

Adibaskoro and Suarjana (2019) assesses a variety of aspects of the implementation of a genetic algorithm to optimize the material cost of a pre-stressed concrete I-girder. The best solution resulting from the optimisation process is presented, identified by being the least costly solution while maintaining compliance with the design code of AASHTO LRFD 2007 [6].

A modified hybrid Genetic Algorithm was used to determine the optimum span number and the optimum cross-sectional properties of multi-span bridges by Aydın and Ayvaz (2013) [7].

Ahsan *et al.,* (2012) proposes an optimization approach to design post-tensioned, pre-tensioned I-girder concrete bridges in order to reduce the total cost of the construction and installation [8].

Sirca Jr and Adeli (2005) presented the total cost optimization of precast, prestressed concrete I-beam bridge systems [9].

For optimum design of pre-stressed concrete beams under flexure a computer program was created. Optimum values of the prestressing force, tendon size, and cross-sectional dimensions are calculated according to the design variables and stress constraints Cagatay [10].

Kaveh *et al.*, [11]; García-Segura *et al.*, [12]; Ohsaki & Fujiwara [13] addressed the optimal cost design of post-tensioned concrete bridges using an optimization algorithm for modified colliding bodies. They found that the proposed optimization algorithm gives a better solution when compared with standard versions of the CBO and PSO algorithms. (here, in this study cost optimization of post tensioned concrete box girder has done by using algorithms but left the suitable cross sections of different spans subjected to different loads.

This present study fills the void in the area of optimization of Prestressed concrete beams using Microsoft Excel Solver and MATLAB programme by considering M_D/M_L ratios.

Table 1: Cross-sectional dimensions for MD/ML.

M_D /M_L	Width of the top flange b_{tf}	Width of the bottom flange b_{bf}	Depth of the section D
0.2	0.50H	0.65H	0.95H
0.3	0.60H	0.60H	1.00H
0.4	0.60H	0.60H	1.00H
0.5	0.64H	0.50H	1.06H
0.7	0.75H	0.30H	1.15H
0.9	0.80H	0.20H	1.20H

II. METHODOLOGY

Calculations using Microsoft Excel Solver: In this investigation, the authors have taken varying spans with varying live loads for the analysis and design. The selected spans were 15, 20, 25 and 30m and live loads were 15kN/m, 20, 25 and 30kN/m. The authors could arrive at equivalent rectangular cross-sections for the above combinations of loads and spans.

For the equivalent rectangular sections, the dead load bending moments were calculated using which MD/ML ratios were determined. Using the Military Engineering Handbook norms, preliminary I or T sections have arrived. For the obtained sections, the eccentricity of the cables and prestressing forces were determined and checked for safety.

III. DESIGN

The authors designed [14, 15] Post-tensioned beam for the spans 15, 20, 25 and 30m with a live load of 15, 20, 25 and 30kN/m run. In this study, the adopted concrete grade was M40, and 7 mm diameter steel wires of characteristics strength 1600 MPa. The beam was designed as a type-1 structure. The strength of concrete at transfer was assumed as 35 MPa and the initial stress in the wires as 1200 MPa.

In this procedure, using the live load moment, and the permissible stresses the section modulus for an equivalent rectangular section is obtained from Eqn. 1.

$$Z_{xx} = \frac{M_L}{\sigma_{CT}' + (1.5\eta - 0.5)\sigma_c'} \qquad (1)$$

The breadth of flanges: From the rectangular section, the first trial 1 section may be selected. The variation in the shape of the trial 1 section does not change the total moment of resistance of a section of the given cross-sectional area significantly. Still, it does cause a significant change in the proportions of the moment of resistance required under beam load and live load. Consequently, when $M_D \leq 0.3M_L$, a section with a slightly larger bottom flange may be used. When M_D lies between $0.3M_L$ and $0.4M_L$, a suitable section is likely to be asymmetrical I section or an asymmetrical I section with a slightly larger top flange. As the ratio of M_D to M_L increases above 0.4, the asymmetry of I section should increase, the top flange being the larger until in the limit, the section assumes a T shape.

The following table may be made use of in selecting the preliminary dimensions of equivalent I section of a rectangular beam of depth H and breadth B = 0.6H.

The thickness of flanges: The thickness of the top flange varies between 0.1D to 015D. For large depths; however, the thickness would be smaller than that given by these proportions. The thickness of the bottom flange should accommodate all the tendons at the mid-span with appropriate cover. The space in between the tendons satisfies the requirements of I/y2. For the preliminary design, a thickness of about 0.2D may be assumed.

The thickness of the web: The more the thickness of the web, the less will be its efficiency. The following requirements govern the web thickness.

Resistance to shear: Adequate cover to tendons along the span of the beam needs to be available for the necessary anchorages.

For the first trial section, a thickness of D/35 + 55 mm+external diameter of the sheath or about 0.125D to 0.15D was adopted. The external diameter of the sheath for 12

Numbers of 7mm diameter and 12 Numbers of 5mm diameter Freyssinet cables are 44 and 34mm respectively.

The predicted dimensions for a particular span and live load is as shown in Fig. 1.

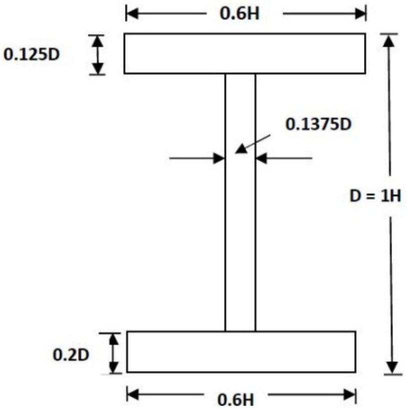

Fig. 1. Predicted dimensions of span.

The sectional properties were calculated for the arrived preliminary section. The value of the cable excentricity and Initial Prestressing force was calculated using Eqns. 2 and 3.

$$\frac{\left(1-\frac{ey_1}{k^2}\right)}{\eta\left(1+\frac{ey_2}{k^2}\right)}=\frac{-\frac{M_D y_1}{I}}{\frac{M_D y_2}{I}+\frac{M_L y_2}{I}}$$

(2)

$$\frac{P_i}{A}\left(1-\frac{ey_1}{\_I}\right)+\frac{M_D y_1}{I}=\sigma_{CT}'=0 \qquad (3)$$

Then the section was checked for the permissible stresses to ensure the safety using Eqns. 4, 5, 6 and 7.

Stress at top fibre at the transfer

$$\frac{P_i}{A}\left(1-\frac{ey_1}{k^2}\right)+\frac{M_D y_1}{I}\leq\sigma_{CT}' \qquad (4)$$

Stress at bottom fibre at the transfer

$$\frac{P_i}{A}\left(1+\frac{ey_2}{k^2}\right)-\frac{M_D y_2}{I}\leq\sigma_C'=(16.9\,MPa) \qquad (5)$$

Stress at the top fibre under service load

$$\frac{\eta P_i}{A}\left(1-\frac{ey_1}{k^2}\right)+\frac{M_D y_1}{I}+\frac{M_L y_1}{I}\leq\sigma_C' \qquad (6)$$

Stress at the bottom fibre under service load

$$\frac{\eta P_i}{A}\left(1+\frac{ey_2}{k^2}\right)-\frac{M_D y_2}{I}-\frac{M_L y_2}{I}\leq\sigma_{CT}' \qquad (7)$$

From the analysis, the authors found that the stress at bottom fibre at transfer is critical, which decides the optimum cross-section. Hence if the value of permissible compressive stress at the bottom fibre was less than the actual stress, the bottom sectional dimensions were varied till a safe section has arrived.

The Ultimate Moment of Resistance values was determined according to the limit state method for the arrived sections, and for all sections, the factor of safety was worked out. Apart from this, the sections were checked for shear and deflection.

The final cross-sections for various spans and live loads can be obtained, which may be the optimum cross-sections. Table 2 shows M_D/M_L of preliminary section as well as for the optimum section, Factor of safety, the width of the top and bottom flange and overall depth of the beam calculated using excel.

IV. ANALYSIS AND DISCUSSION ON RESULTS

Table 2 shows the M_D/M_L of the equivalent section for arriving at I or T section. The factor of safety values ranges between 1. 5 to 1.62 for the economic sections. From the observed values, it can be found that for the greater spans, the factor of safety increases marginally. After arriving at the final sections, modified M_D/M_L ratios were worked out and presented in the table. Table 2 shows, the final factor for the calculation of the widths of the top and bottom flanges and overall depth of the beams.

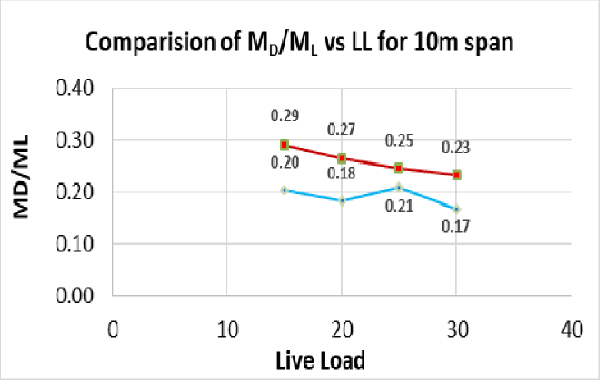

Fig. 2. M_D/M_L values for 10m span for varying live loads.

Table 2: Values obtained by excel calculations.

Span in m	LL in kN/m	M_D/M_L (P)	M_D/M_L (F)	FOS	b_{tf}	b_{bf}	D
10	15	0.29	0.20	1.50	0.65H	0.67 H	0.97 H
10	20	0.27	0.18	1.50	0.59H	0.67 H	0.97 H
10	25	0.25	0.21	1.49	0.53H	0.66 H	0.97 H
10	30	0.23	0.17	1.52	0.62 H	0.67 H	0 .95 H
15	15	0.50	0.29	1.46	0.67 H	0.56 H	1.06 H
15	20	0.46	0.31	1.50	0.61 H	0.63 H	1.01 H
15	25	0.42	0.31	1.50	0.62 H	0.62 H	1.01 H
15	30	0.40	0.27	1.50	0.62 H	0.62 H	1.01 H
20	15	0.74	0.45	1.56	0.76 H	0.40 H	1.15 H
20	20	0.67	0.41	1.50	0.65 H	0.54 H	1.07 H
20	25	0.62	0.41	1.50	0.65 H	0.52 H	1.06 H
20	30	0.59	0.35	1.48	0.65 H	0.55 H	1.06 H
25	15	0.99	0.58	1.63	0.80 H	0.38 H	1.21 H
25	20	0.90	0.52	1.61	0.80 H	0.38 H	1.20 H
25	25	0.84	0.50	1.57	0.75 H	0.49 H	1.15 H
25	30	0.79	0.43	1.59	0.76 H	0.44H	1.15H
30	15	1.27	0.75	1.59	0.80 H	0.40H	1.21H
30	20	1.15	0.65	1.60	0.81 H	0.40H	1.20H
30	25	1.07	0.59	1.61	0.80 H	0.39H	1.21H
30	30	1.01	0.55	1.62	0.80H	0.39H	1.20H

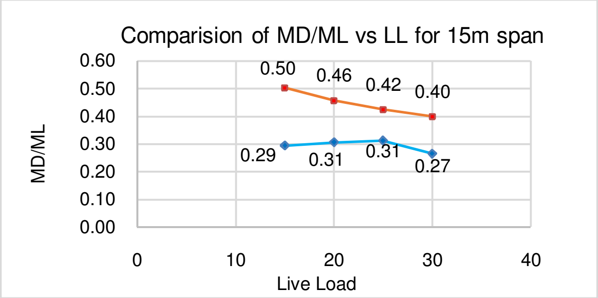

Fig. 3. M_D/M_L values for 15m span for varying live loads.

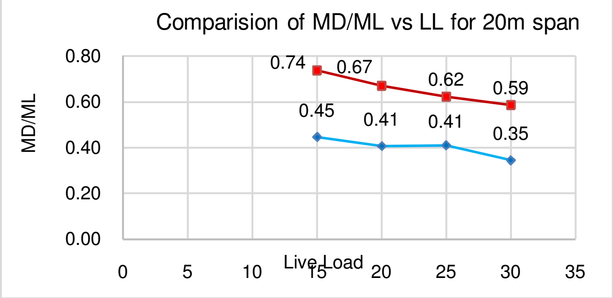

Fig. 4. M_D/M_L values for 20m span for varying live loads.

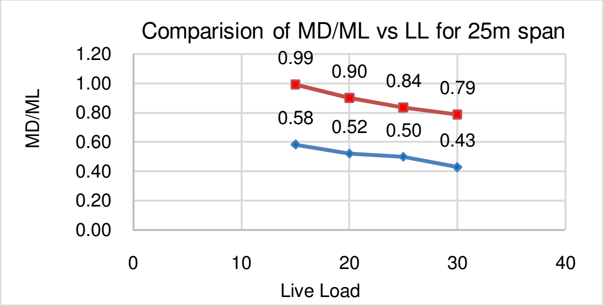

Fig. 5. M_D/M_L values for 25m span for varying live loads.

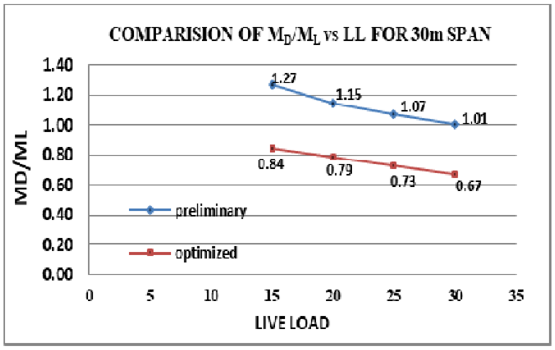

Fig. 6. M_D/M_L values for 30m span for varying live loads.

Graphs were drawn between M_D/M_L ratios obtained for preliminary design and also for the final design for various spans, as shown in Fig. 2, 3, 4, 5 and 6.

V. MATLAB PROGRAMMING

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment in which familiar mathematical notations express problems and solutions. Table 3 shows the results obtained from the analysis and design of prestressed concrete beams using MATLAB tool. The values obtained using excel and MATLAB programming were compared and presented, as shown in Table 4.

Table 3: Values obtained by MATLAB Programming.

Span in m	Live Load in kN/m	M_D/M_L	M_D/M_L (F)	FoS	b_{tf}	b_{bf}	D
10	15	0.29	0.16	1.51	0.65H	0.67H	H
10	20	0.27	0.14	1.52	0.60H	0.67H	H
10	25	0.25	0.26	1.48	0.66H	0.66H	H
10	30	0.23	0.24	1.55	0.63H	0.68H	H
15	15	0.50	0.37	1.50	0.72H	0.58H	1.07H
15	20	0.46	0.35	1.54	0.72H	0.66H	1.01H
15	25	0.42	0.33	1.54	0.64H	0.65H	1.05H
15	30	0.40	0.29	1.55	0.64H	0.65H	1.05H
20	15	0.74	0.47	1.52	0.76H	0.23H	1.16H
20	20	0.67	0.45	1.52	0.75H	0.25H	1.15H
20	25	0.62	0.43	1.53	0.72H	0.26H	1.13H
20	30	0.59	0.39	1.56	0.72H	0.27H	1.12H
25	15	0.99	0.62	1.55	0.81H	0.20H	1.21H
25	20	0.90	0.58	1.57	0.80H	0.20H	1.20H
25	25	0.84	0.53	1.57	0.78H	0.12H	1.18H
25	30	0.79	0.45	1.58	0.77H	0.23H	1.17H
30	15	1.27	0.84	1.60	0.80H	0.40H	1.21H
30	20	1.15	0.79	1.65	0.81H	0.40H	1.20H
30	25	1.07	0.73	1.65	0.80H	0.39H	1.21H
30	30	1.01	0.67	1.69	0.80H	0.39H	1.20H

Table 4: M_D/M_L.

Span in m	Live Load in kN/m	M_D/M_L (MATLAB)	M_D/M_L (MS-Excel)
10	15	0.16	0.20
10	20	0.14	0.18
10	25	0.26	0.21
10	30	0.24	0.17
15	15	0.37	0.29
15	20	0.35	0.31
15	25	0.33	0.31
15	30	0.29	0.27
20	15	0.47	0.45
20	20	0.45	0.41
20	25	0.43	0.41
20	30	0.39	0.35
25	15	0.62	0.58
25	20	0.58	0.52
25	25	0.53	0.50
25	30	0.45	0.43
30	15	0.84	0.75
30	20	0.79	0.65
30	25	0.73	0.59
30	30	0.67	0.55

Graphs were drawn comparing the MD/ML values obtained for various spans and different live loads.

From Fig. 7, it was found that M_d/M_L ratio for getting the optimized section is not accurately predictable due to the irregularities shown in the curve compared with the M_D/M_L. ratio for getting the preliminary sections. These irregularities lead to the conclusion that for a smaller span of 10m, it is preferable to go for rectangular sections instead of I sections.

Fig. 8 to 11 shows the comparison graphs for M_D/M_L ratio vs. Live load for different spans. It was found from the curves that the M_D/M_L curves obtained for optimum sections using MATLAB can predict the optimum sections more accurately than the sections obtained using Excel calculations. The obtained data will enable us to arrive at the suitable optimum sections for spans ranging between 15 and 30m for live loads varying between 15kN/m and 30kN/m.

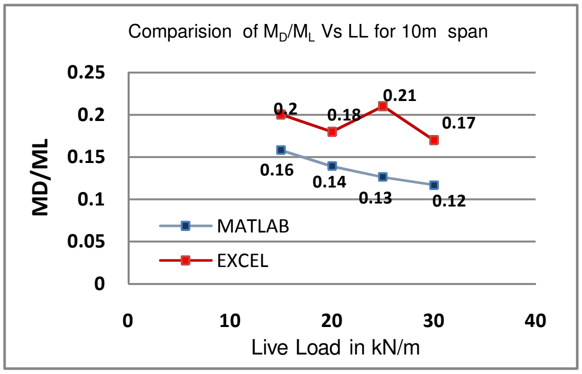

Fig. 7. M_D/M_L values for 10m span for varying live loads.

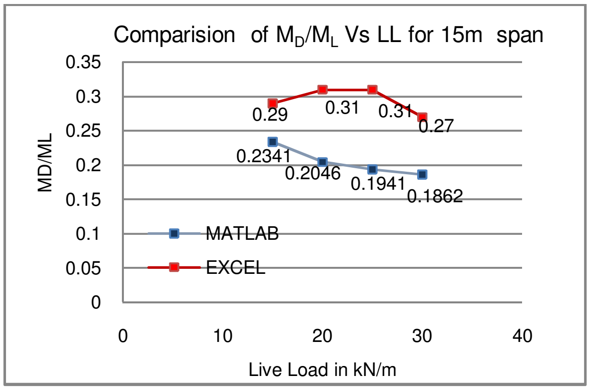

Fig. 8. M_D/M_L values for 15m span for varying live loads.

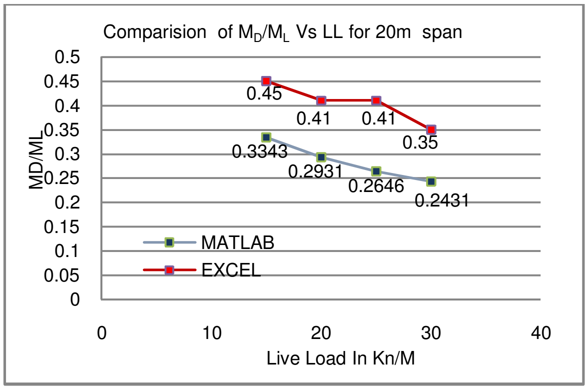

Fig. 9. M_D/M_L values for 20m span for varying live loads.

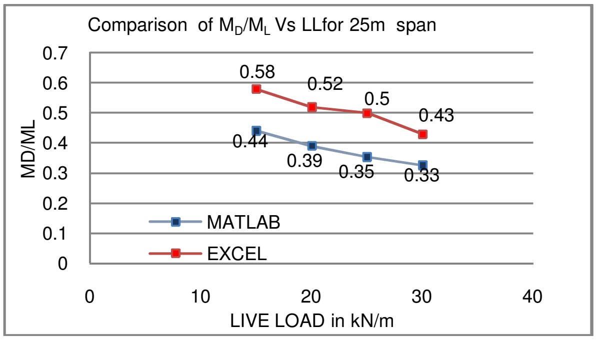

Fig. 10. M_D/M_L values for 25m span for varying live loads.

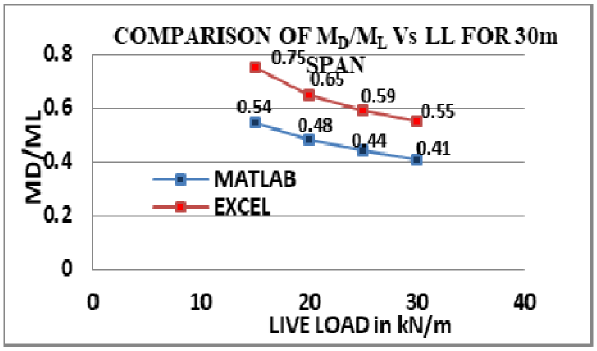

Fig. 11. M_D/M_L values for 30m span for varying live loads.

VI. OVERVIEW AND CONCLUSIONS

In this study, an attempt made to design the Type I Post-Tensioned Prestressed Concrete I beam for various spans ranging from 10m to 30m using the existing norms for arriving at the cross-sections using the Military Engineering Handbook lead to arriving at optimum sections. The loads considered in this study were ranging from 15kN/m to 30kN/m. The issues out of the earlier work done as per the Literature survey was sorted out by rigorous calculations and trials. Based on the obtained final sections, the norms for getting the optimum sections have arrived for the above parameters.

Apart from the excel calculations, we did attempt to arrive at the optimum sections using MATLAB. The comparisons on the results obtained using excel calculations, and MATLAB programming are as given below:

The optimum design of sections was decided based on the maximum stress at the bottom fibre of the prestressed concrete girder at the transfer of prestressing, which is more critical than other conditions. M_D/M_L values obtained using MATLAB coding and Excel for different spans and live loads in this study will provide the optimum sections without much calculation.

–It was found that M_D/M_L ratio for getting the optimized section is not accurately predictable due to the irregularities shown in the curve compared with the MD/ML ratio for getting the preliminary sections. These irregularities lead to the conclusion that for a smaller span of 10m, it is preferable to go for Rectangular sections instead of I sections.

–It was observed from the graphs that the M_D/M_L curves obtained for optimum sections are in a similar pattern to M_D/M_L curves obtained for preliminary sections and are almost linear in all the cases.

–It was found that M_D/M_L ratios obtained from MATLAB and EXCEL for optimized sections are not uniform which leads to the conclusion that for a smaller span of 10m, it is preferable to go for Rectangular sections instead of I sections.

–From the comparison of M_D/M_L values obtained through Excel and MATLAB for the optimum section, it was found that M_D/M_L ratios obtained using MATLAB predicts the optimum section more precisely than the optimum section obtained using Excel calculations.

–It has been noticed that the shear resistance of all the sections under cracked and uncracked conditions were sufficiently safe.

–It was found that the upward deflections due to prestressing force and downward deflections due to service loads were well within the permissible limits as stipulated [16].

REFERENCES

[1]. Bhawar, P. D., Wakchaure, M. R., & Nagare, P. N. (2015). Optimization of prestressed concrete girder. *International Journal of Research in Engineering and Technology (IJRET) Eissn*, *4*, 2319-3163.

[2]. Aydın, Z., & Ayvaz, Y. (2010). Optimum topology and shape design of prestressed concrete bridge girders using a genetic algorithm. *Structural and Multidisciplinary Optimization*, *41*(1), 151-162.

[3]. Quaranta, G., Fiore, A., & Marano, G. C. (2014). Optimum design of prestressed concrete beams using constrained differential evolution algorithm. *Structural and Multidisciplinary Optimization*, *49*(3), 441-453.

[4]. Ma, Q., Ohsaki, M., Chen, Z., & Yan, X. (2019). Multi-objective optimization for prestress design of cable-strut structures. *International Journal of Solids and Structures*, *165*, 137-147.

[7]. Chen, Y., Li, Q., Zhang, Z., Cai, K., Zhou, M., Sheng, T., & Wu, H. (2019). Optimum design for unbonded posttensioned precast split shear wall system using genetic algorithm. *The Structural Design of Tall and Special Buildings*, *28*(5), e1582.

[8]. Adibaskoro, T., & Suarjana, M. (2019). Prestressed Concrete I-Girder Optimization via Genetic Algorithm. *Journal of Engineering and Technological Sciences*, *51*(2), 170-183.

[9]. Aydın, Z., & Ayvaz, Y. (2013). Overall cost optimization of prestressed concrete bridge using genetic algorithm. *KSCE Journal of Civil Engineering*, *17*(4), 769-776.

[10]. Ahsan, R., Rana, S., & Ghani, S. N. (2012). Cost optimum design of posttensioned I-girder bridge using global optimization algorithm. *Journal of Structural Engineering*, *138*(2), 273-284.

[11]. Sirca Jr, G. F., & Adeli, H. (2005). Cost optimization of prestressed concrete bridges. *Journal of Structural Engineering*, *131*(3), 380-388.

[12]. Cagatay, I. H., Dundar, C., & Aksogan, O. (2003). Optimum design of prestressed concrete beams by a modified grid search method. *Structural Engineering and Mechanics*, *15*(1), 39-52.

[13]. Kaveh, A., Maniat, M., & Naeini, M. A. (2016). Cost optimum design of post-tensioned concrete bridges using a modified colliding bodies optimization algorithm. *Advances in Engineering Software*, *98*, 12-22.

[14]. García-Segura, T., Yepes, V., Frangopol, D. M., & Yang, D. Y. (2017). Lifetime reliability-based optimization of post-tensioned box-girder bridges. *Engineering Structures*, *145*, 381-391.

[15]. Ohsaki, M., & Fujiwara, J. (2003). Developability conditions for prestress optimization of a curved surface. *Computer methods in applied mechanics and engineering*, *192*(1-2), 77-94.

[16]. Raju, N. K. (2006). Prestressed concrete. Tata McGraw-Hill Education.

[17]. IS: 1343-2012 “Prestressed Concrete-Code of Practice (Second Revision), Bureau of Indian Standards, New Delhi, India.

How to cite this article: Tensing, D., Vincent Sam Jebadurai S., Paulson, J., Rahul A. V. and Jefrey, K. (2020). Optimization in the Design of Prestressed Concrete Girders using Excel and MATLAB. *International Journal on Emerging Technologies*, *11*(2): 420–426.