OPTIMIZATION OF PRESTRESSED CONCRETE GIRDER

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Abstract

Bridge construction today has achieved a worldwide level of importance. Bridges are the key elements in any road network Use of prestressed concrete I girder bridge is gaining popularity in bridge engineering fraternity because of its better stability, serviceability, economy, aesthetic appearance and structural efficiency.

This paper concerned idea about prestressed concrete.In the method of prestressing two types are consider that pre tensioning and post tensioning .At the time of prestressing different losses are consider. These are the losses due to elastic shortening, friction losses, relaxation losses, losses due to creep and shrinkage. In this way total amount of losses in pretensioning and post tensioning calculate and detailed information has given in this report.

The objective is to minimize the total cost in the design process of the bridge system considering the cost of materials like steel, concrete, tendons etc. For a particular problem the design variables considered for the cost minimization of the bridge system, are depth of girder, various cross sectional dimensions of the girder, number of tendons, A programme is developed for analysis and designing an low cost prestressed girder in MATLAB R2010a software. The optimtool is used to find out minimum cost of structure Illustrative case of prestressed girder presented and discuss by using active set method from optimtool. Optimization problem is characterized by considering design variables and bound constraints are according to AASHTOO Standards ,IRC 21-2000 bridge specifications .The proposed cost optimization approach is compared with an existing project which leads to a considerable cost saving while resulting in feasible design.

Keywords: *Post tension I girder, Conventional design, Optimal design, MATLAB Software etc…*

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1. INTRODUCTION OF PRESTRESSED CONCRETE BRIDGES

The Principal of presstressed concrete has been widely applied for the design of bridges. The prestressed members are light and best suited for architectural treatment. Prestressing technique eliminates the cracking of concrete. Presence of cracks lowers the capacity of structure to bear reversal of stresses, impact, vibration and shock. This reduces the maintenance cost and provides smoother deck for high speed driving. The prestressing technique increases the shear capacity of concrete.

Prestressed concrete bridges of medium and long span are generally of three basic types:-
i) Precast I beam with an in-situ reinforced concrete deck either made continuous by means of in- situ pier diaphragms and continuity steel by suspending them between in situ umbrella.
ii) Continuous in-situ solid post-tensioned slabs, in spans up to 35 m.
iii) Continuous hollow box girder bridges, usually in-situ .These may be constructed on ground supported false work, or by free cantilever erection methods.

The prestressing can be either pretensioning or post tensioning .The choice of particular method for any given bridge would depend upon the availability of and proximity of pretensioning plant and equipment, size, availability of post tensioning know-how and equipment ,size of members, number of units of similar type, etc .Pretensioning is usually economical with straight tendons. The Post-tensioning can be structurally advantageous with draped tendons. Post-tensioning is well suited for prestressing at a construction site without the need for factory type installations .The unit cost for post –tensioning is higher as compared to pretensioning .This is because post tensioning requires individual tensioning, special anchorages, sheath and grouting. The cast of post –tensioning devices is higher because they are covered by patents which restrict the user to purchase material and equipment from the patent holders only .All post-tensioned girders are invariably with bonded tendons.

The precasting industry in recent years has become very popular all over the world due to efficient management and outstanding quality control procedure. The major limitations to presstressed construction when it comes to hauling and erecting have been the length and weight limits. For bridge structure two basic precast sections are produced:-I beam sections to be used with a cast –in –place deck.

Presstressed concrete is ideally suited for the construction of medium and long span bridges. Ever since the development of prestressed concrete by Freyssinet in the early 1930s, the material has found extensive application in the construction of long-span bridges, gradually replacing steel which needs costly maintenance due to the inherent disadvantage of corrosion under aggressive environment conditions. One of the most commonly used forms of superstructure in concrete bridges is precast girders with cast-in-situ slab. This type of superstructure is generally used for spans between 20 to 40 m. T or I-girder bridges are the most common example under this category and are very popular because of their simple geometry, low fabrication cost, easy erection or casting and smaller dead loads [21].

2. METHODOLOGY

In this project gives an idea about design the prestressed girder. For the design I section is used. This report gives the two method of designing girder. Firstly by conventional method and second is optimization method. With help of mathematical analysis, manual iteration and most of human efforts conventional design method is carried out.

2.1 Conventional Method of Design

In conventional structure design process, the design method proposes a certain solution that is corroborated by mathematical analysis in order to verify that the problem requirements or specifications are satisfied. The process undergoes many manual iterations before the design can be finalized making it is slow and very costly process. There is no formal attempt to reach the best design in the strict mathematical sense of minimizing cost, weight or volume. The process of design is relied solely on the designer's experience, intuition and ingenuity resulting in high cost in terms of times and human efforts.

2.2 Design Example

Design a post tensioned PSC Girder for effective span of 20m; simply supported live load on girder is 2.5KN/m2, Use M45 and any type of cable (Multistrand cable). Slab thickness=115mm. Short span of slab=3m, WPL/FFL on slab=0.75KN/m2,Ro=0.85.

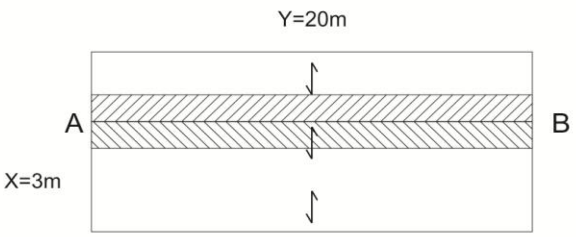


Fig.1: Plan of simply supported PSC girder with deck slab

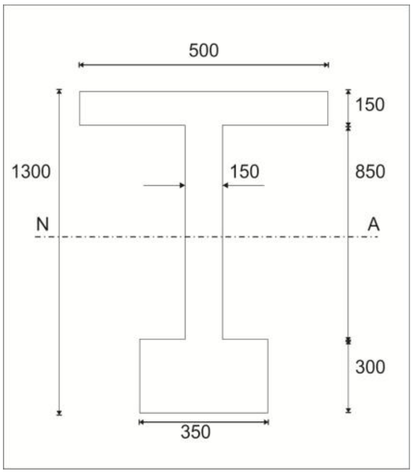


Fig. 2: Cross section of prestressed concrete girder

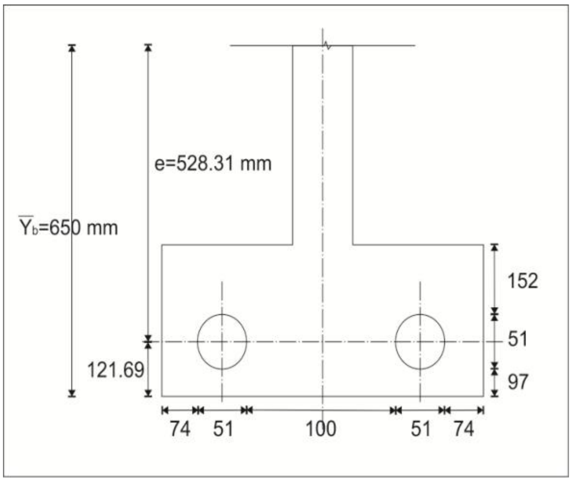


Fig.3: Arrangement of cable at mid span section

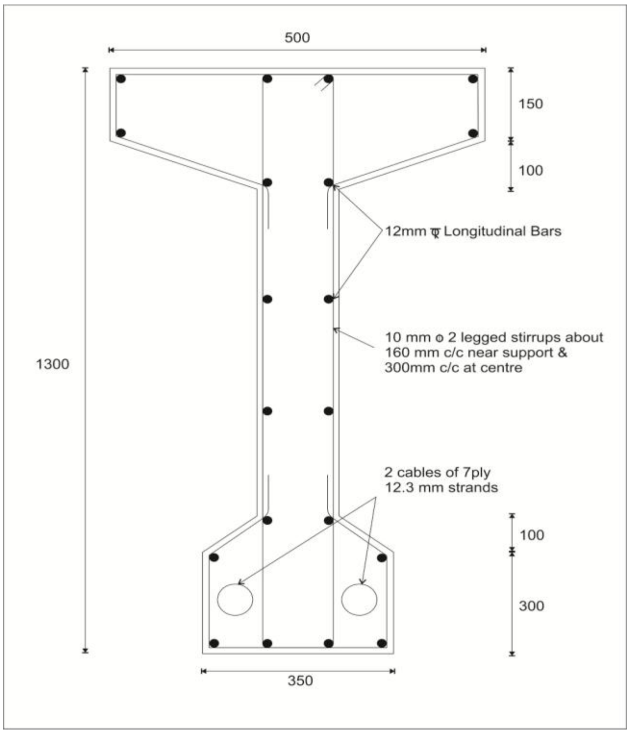


Fig.4:- Reinforcement details on midspan section

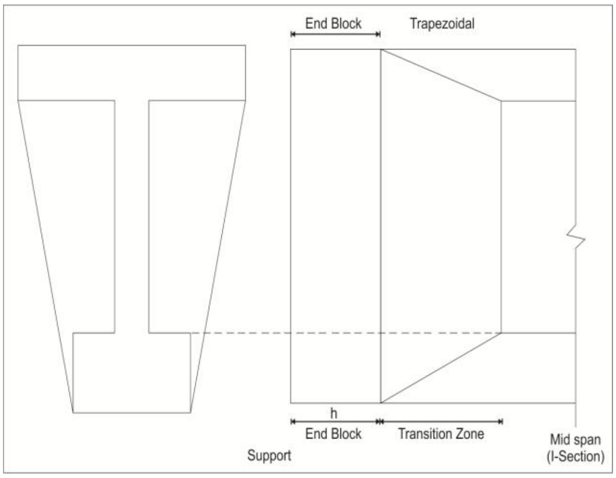


Fig.5:-Trapezoidal end block view and transition zone

2.3 Optimization Method of Design

The ultimate aim of all such decision is to either minimize the effort required or maximize the desire benefit. Since the effort required or the benefit desired in any practical situation can be expressed as a function of a certain design variables, optimization can be defined as the process of finding the conditions that give the minimum or maximum value of a function. Without loss of generality optimization can be taken to mean minimization of a function since the maximum of a function can be found be seeking the minimum of the negative of the same function.

2.4 Problem Formulation

2.4.1. Description of Design Variables

In prestressed concrete bridge girder design five design variables are considered. Following fig. shows cross section of girder with design variables.
X1= Height of Girder
X2 = width of web
X3 = Width of Bottom Flange
X4= Thickness of Bottom Flange
X5 = Number of cables

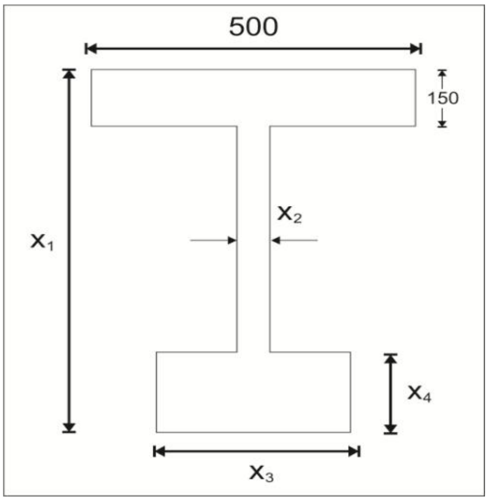


Fig.6:-Cross section of post tension girder showing different design variables

2.4.2 Description of constraints

The bound on design variable is considered as constraints. These are specified limitation (upper or lower limit) on design variables which are derived from geometric requirements (superstructure depth, clearances etc.), minimum practical dimension for construction, code restriction etc. The lower and upper limits of deck slab reinforcement are considered according to AASHTO standard specification,[12,19,22] .The constraint is defined as

$$XL \leq X \leq XU$$

Where
X = Design variable.
XL = Lower limit of the design variable.
XU = Upper limit of the design variable

Table 1. Design variables with constraints

Sr. No.	Design Variables	Constraints
1.	X1= Height of Girder	$1000 \leq X1 \leq 3500$
2.	X2 = width of web	$b \leq X2 \leq 300$
3.	X3=Width of Bottom Flange	$300 \leq X3 \leq S$
4.	X4=Thickness of Bottom Flange	$a \leq X4 \leq 600$
5.	X5= No. of Cables	$1 \leq X5 \leq 20$

a = clear cover + duct diameter; b = clear cover + web rebars diameter + duct diameter;, S= Girder spacing

2.4.2 Objective Function

The objective function in the present optimization problem is the cost of PSC I girder for bridge whose main components are cost of concrete, and pre stressing steel. The objective function is a function of design variables the value of which provides the basis for choice between alternate acceptable designs [23] .In structural design the objective function is usually cost minimization.

The cost function F (cost) is:

F (Cost) = Qconc. x Cconc. + Qsteel x Csteel + Qcable x Ccable

Where, Qconc. is the quantity of concrete in m3
Cconc. is the unit cost of concrete in Rs/m3
Q steel is the quantity of steel in kg.
C steel is the unit cost of steel in Rs/kg.
Qcable is the quantity of cable in kg.
Ccable is the unit cost of cable in Rs/kg.

3. RESULTS AND DISCUSSION

This is constrained nonlinear programming problem for the numerical solution of post tension I girder structure using MATLAB, optimtool.A bound constraint for upper & lower limits of design variables are derived from geometric requirements, minimum practical dimension for construction, code restriction etc. and objective function has been prepared for various width and thickness of top flange of girder and the also according to different concrete grade. Following are the input parameters of post tension I girder which is used in the optimtool for making bound constrained equation and objective equation in optimtool.

3.1 Optimization for Post Tension I Girder

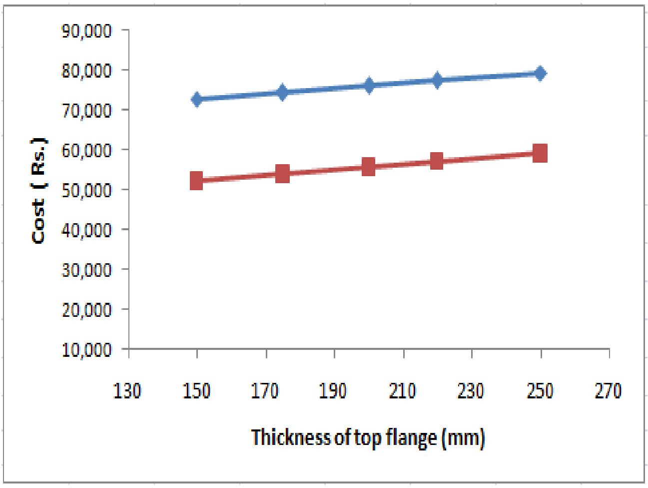
The programs developed were applied to obtain optimal solution for 1300 mm height of girder. Optimal values are obtained in three cases according to three different grades of concrete. Problem is solved by M45 grade but it compares with the M50 grade. Each case includes varies the top flange dimensions and compared with conventional values.

3.1.1 For M45 grade of concrete

1) **CASE-I** As top flange width constant (TFw) and vary thickness (TFt).
2) **CASE-II** As Top flange width vary (TFw) and thickness constant (TFt).
3) **CASE-III** As Both top flange width (TFw) and thickness (TFt) vary.
4) **CASE-IV** As top flange width increases (TFw) and thickness (TFt) decreases.

Table -1: **CASE-I** As top flange width constant (TFw) and vary thickness (TFt).

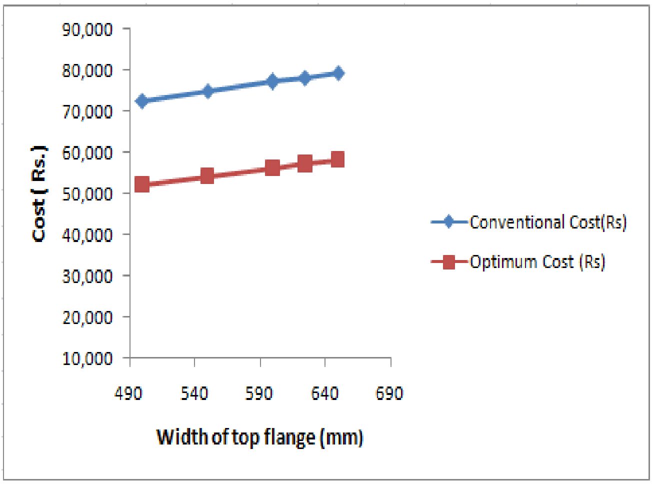
Sr. No.	Top Flange Width (TFw) in mm	Top Flange Thickness (TFt) in mm	Conventional Cost(Rs)	Optimum Cost (Rs)
1	500	150	72,713	52,184
2	500	175	74,402	53,931
3	500	200	76,091	55,678
4	500	220	77,442	57,075
5	500	250	79,469	59,171



Graph-1:-Case-I Comparison of optimum and conventional cost

Table -2: **CASE-II** As Top flange width vary (TFw) and thickness constant (TFt).

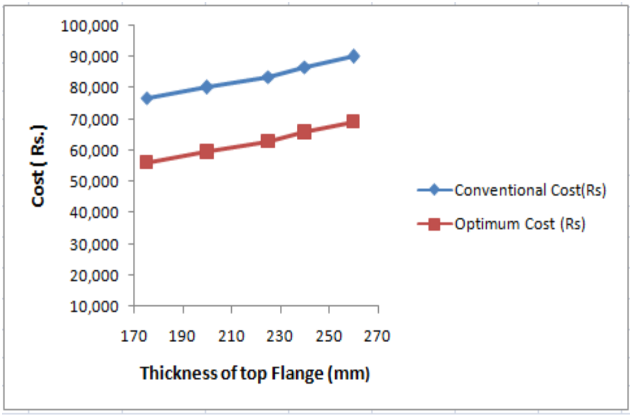
Sr. No.	Top Flange Width (TFw) in mm	Top Flange Thickness (TFt) in mm	Conventional Cost(Rs)	Optimum Cost (Rs)
1	500	150	72,713	52,184
2	550	150	74,919	54,173
3	600	150	77,125	56,168
4	625	150	78,228	57,155
5	650	150	79,331	58,149



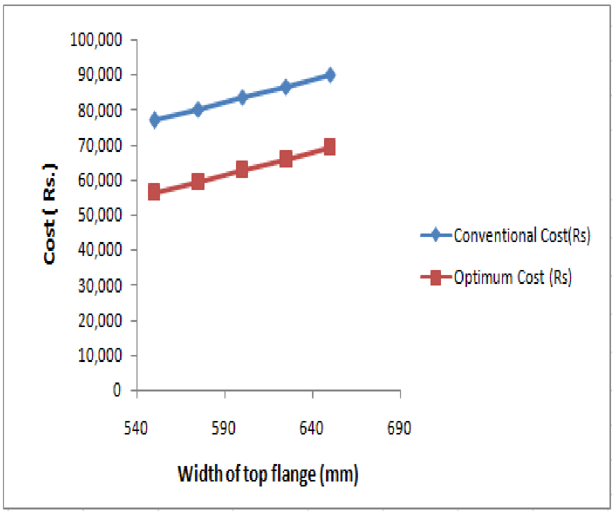
Graph-2:-Case-II Comparison of optimum and conventional cost

Table -3: **CASE-III** As Both top flange width (TFw) and thickness (TFt) vary.

Sr. No.	Top Flange Width (TFw) in mm	Top Flange Thickness (TFt) in mm	Conventional Cost(Rs)	Optimum Cost (Rs)
1	550	175	76,859	56,175
2	575	200	80,154	59,426
3	600	225	83,700	62,933
4	625	240	86,571	65,741
5	650	260	90,081	69,205



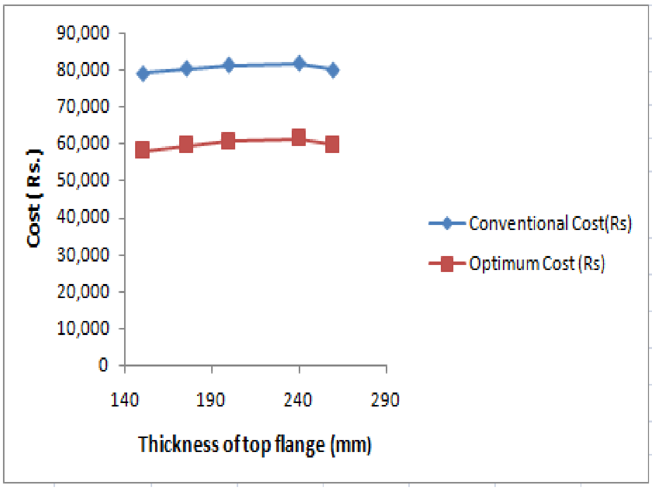
Graph-3:-Case-III Comparison of optimum and conventional cost



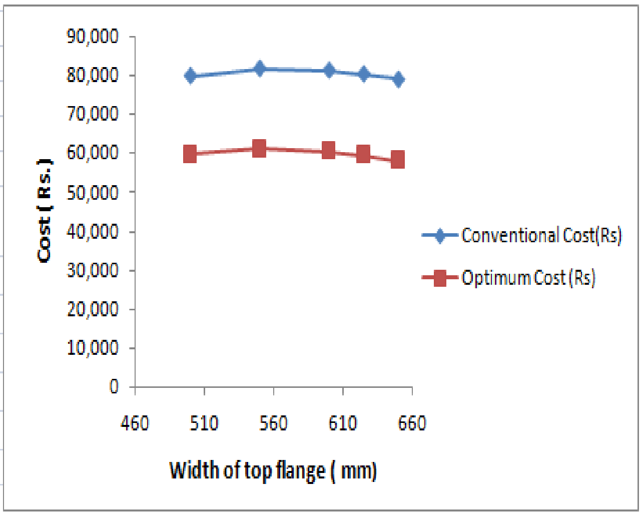
Graph-4:-Case-III Comparison of optimum and conventional cost

Table -4: CASE-IV As top flange width increases (TFw) and thickness (TFt) decreases.

Sr. No.	Top Flange Width (TFw) in mm	Top Flange Thickness (TFt) in mm	Conventional Cost(Rs)	Optimum Cost (Rs)
1	500	260	80,145	59,870
2	550	240	81,904	61,380
3	600	200	81,508	60,676
4	625	175	80,545	59,540
5	650	150	79,331	58,149



Graph-5:-Case-IV Comparison of optimum and conventional cost



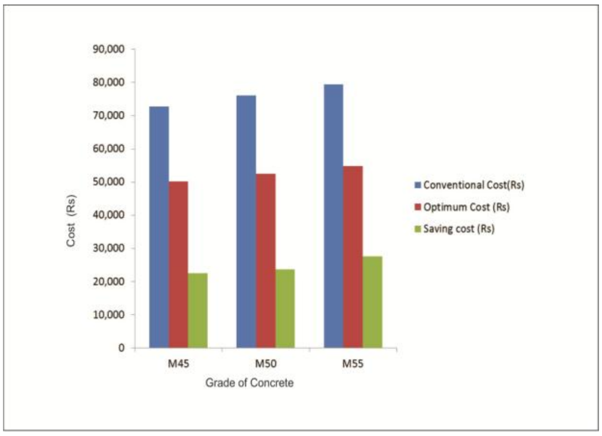
Graph-6:-Case-IV Comparison of optimum and conventional cost

3.2 Comparison of Conventional, Optimum and Saving Cost for different Grade of Concrete with TFw = 500mm, TFt = 150 mm.

For conventional design take top flange width 500mm & thickness is 150 mm.This values are taken for different grade of concrete. Calculate the conventional cost and compare result with the optimum cost and also calculate the saving cost. As conventional cost increase, optimum cost and saving cost is also increases. These are shown in table below:-

Table No-5: Cost comparison of conventional and optimum cost as TFw =500 and TFt = 150 mm, changes grade of concrete

(TF w)	(TF)	Grade of Concrete	Conventional Cost(Rs)	Optimum Cost (Rs)	Saving cost
500	150	M45	72,713	52,184	20,529
		M50	76,091	54,609	21,482
		M55	79,470	57,034	22,436



Graph -7: Comparison of optimum, conventional and saving cost

4. RESULT ANALYSES

In the analysis, objective function i.e. for cost is explained for three different grade of concrete and each case include varies the top flange dimensions and compared with conventional values are given in graph no. 1 to 6. In this optimal design cost saving is same .As in four cases are taken in that case I constant TFw and vary TFt then conventional & optimum cost increases with increase in TFt .then case II constant TFt and vary TFw then also conventional & optimum cost increases with increase in TFw.

In Case III both TFw and TFt varies then both cost increases. and lastly the case IV TFw increases and decreases the TFt then conventional & optimum cost increases at certain point and then both the values decreases. These cases are same for three different grade of concrete. As the grade increase the conventional cost and optimum cost is also increases.

5. CONCLUSION

- From graph, for conventional and optimal design consideration; it shows that overall cost of structure can be reduced by using optimization technique with stability.
- The conventional design procedure aim at finding an acceptable or adequate design which merely satisfies the functional and other requirements of the post tension I girder In general ,there will be more than one acceptable design based on assumptions. So, it is difficult to co-relate with different parameters .The purpose of optimization has to choose the best one of the many acceptable design.

ACKNOWLEDGEMENTS

I take this opportunity to thank H.O.D, staff members of Civil Engineering Department, Amrutvahini college of engineering, Sangamner, library staff for their assistance useful views and tips. A word of thanks is also reserved for all my batch mates for their selfless help, support and entertaining company.

The authors can acknowledge any person/authorities in this section. This is not mandatory.

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