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Optimization of Box Girder Bridge Using Genetic Algorithm Method

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Abstract: *Box girder is widely used in bridge engineering because of its economy, aesthetic appearance. Now a day it is easy to get safe design due to recent advances in design field but safety with economy is the basic need of present generation, hence it is necessary to go for optimum design. In large span bridges pre stressed concrete is adopted. And thus in present study PSC box girder of span 40m is used for the study. And the loadings are taken as per Indian Road Congress loadings (IRC:6-2014) pre-stressed concrete code (IS:1343-2012) and IRC: 18-2000 specifications. The box girder is designed by limit state method. A computer programme is written in MATLAB-CSI API software for optimization process using genetic algorithm method, and analysis results are retrieved from CSI bridge software to carry out optimization process.*

Keywords-*Box girder bridge, CSI Bridge, Genetic algorithm, MATLAB-CSI API, Optimization.*

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I. Introduction

Bridge is a structure which provides the passage over an obstacle without obstructing the way beneath. It is a key element for road, because of its better structural efficiency and stability. And in most of the cases pre-stressed concrete bridges are used, pre-stressed concrete is mainly suited for the construction of medium and large span bridges, the pre-stressed concrete was development byFreyssinet in the year 1930, this material has found maximum application in the construction of long span bridge[1], this concrete is replacing the use of steel]due to its inherent disadvantages of corrosion under worse atmospheric condition.

Bridges of span ranges 10m to 20m solid slabs are used, while for the span 20m to 40m T- beam slab deck are suitable. Multi or single cell box girder bridges are usually preferred for larger spans of the range 30m to 70m. pre-stress concrete is ideally used for continuous large span bridges in which the precast box girder bridge of variable depth is used for the span of 50m. pre-stressed concrete has widely used throughout the world for continuous, simply supported, cantilever, suspension, and bridle chord type bridges in the span range of 20m to 500m.MohmmedA.Al-Osta& Abdul K. Azad[2],minimized thetotal cost of single cell post tensioned continuous two span box girder bridge using gradient method, and they have concluded that a combination of long and short tendons for either a two span or three span bridge girder, variable depth is necessary requisite to achieve an economical design,

II. Need of optimization

For single design problem there are many acceptable designs, among all these designs one which is economical will satisfy both engineering and structural standards as well as economical need. The process of finding best and economic results with maximum benefit at minimum cost is called optimization.

Due to recent advances in structural designing field it is easy to get a safe design but it is difficult to find the economical design, hence optimization technique is necessary to get most economical design. Which is advantageous in many ways such as material saving, reducing the concrete usage. Hence optimization has gained good scope in structural engineering.
In this paper the cost optimization of box-girder bridge is carried out.

III. Modelling and Analysisof box girder

The analysis of box girder is carried out by using CSI bridge version20 software, this software applies an algorithm that idealizes the box girder as a torsionally stiff single spine beam, and whereas in multi-cell concrete box girder bridge it analysis the superstructure on girder by girder and it ignores the torsion effect. This software helps user to use separate girder results directly from model. CSI software gives the user a different ways of addressing distribution of loads to each girder.The CSI Application Programming Interface (API) is a powerful tool that allows users to automate many of the processes required to build, analyse, and design models and to obtain customized analysis and design results. It also allows users to link CSiBridge with third-party software, providing a path for two-way exchange of model information with other programs.

IV. Optimization method

4.1 Introduction

Optimization has become more popular in structural engineering field from few decades; reason behind this is many industry, in taking technical and management decision at various stages. The main aim of all such decision is to minimize the objective functions. Optimization is a process of finding the optimum value of a function under a given condition, objective function can be anything such as optimum cost, weight and optimum sections, depending upon the problem.

4.2 Genetic algorithm method

It is non-traditional search technique in most of cases it will find the most economical global optimum solutions. This technique starts with a set of design points with available variables, it works on the principal of natural genetic and natural selection. From the early set of design points, new set of design points are generated and weaker points are removed.

The basic idea of genetic algorithm was developed in the year 1960 and early 1970s, by John Holland[4], hence it is conception, and this method is used as a tool in artificial intelligence and computer programing. Thus this search is based on Darwin's theory of survival of fittest. Genetic algorithm gets its name so hence it uses basic elements of natural genetics.

The genetic algorithm differs from other methods in several aspects

I. Genetic algorithm works with a coding of the set of feasible point rather than the set generated itself.
II. It finds from a random set of points rather than the set itself.
III. Derivatives of the objective function are not used.
IV. It uses random operation in each iteration process.

The flow chart of genetic algorithm illustrates the working process

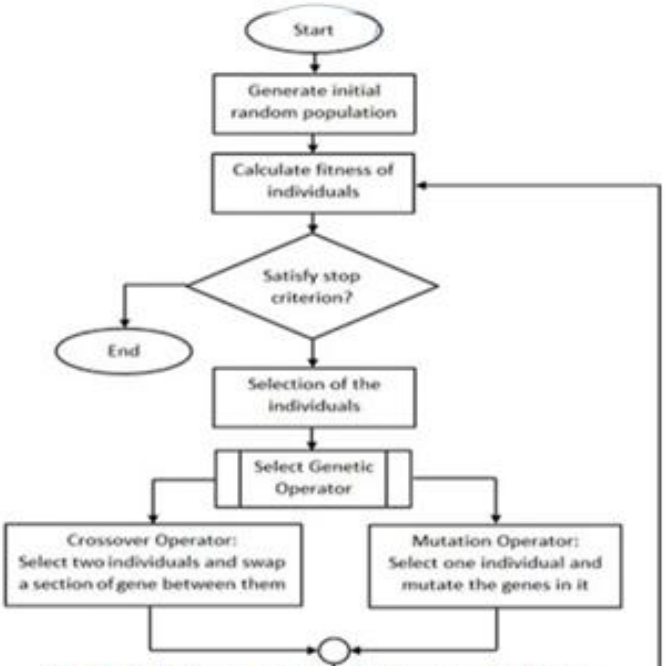

Fig 1: Flow chart of genetic algorithm

V. Optimization of box girder

5.1 Introduction to optimizer

Optimizer is built on bases of genetic algorithm programming; the problem is automated by writing a program in MATLAB software which is user Friendly and flexible for optimization of PSC box-girder. Few important features of the program are mentioned bellow.

- CSI bridge software is linked through API to MATLAB to retrieve the result from it and to carry out the optimization process.

- The user has to enter variables, constraints and the number ofindividuals per subpopulations and maximal Number of generations and generation gap.
- The user has to enter permissible stresses and permissible deflection for the grade of concrete selected as per code.

5.2 Testing of optimizer

The optimizer is checked to make sure that optimizer is working properly, and it is tested with simple example by referring literature [7],

Example:

The 10bar truss problem is solved by referring literature. Fig.2 shows the 10-bar truss with dimensions, loading, and other required parameters. The assumed data are: *E* = 104 ksi (6.89 x 104 MPa), *ρ* =0.10 lb/in3 (2,770 kg/m3).

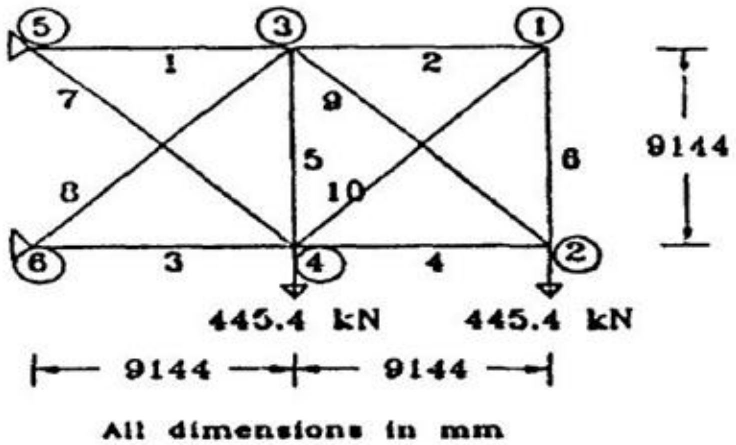

Fig 2: 10 Bar truss problem detailing

1) Constraints – 2
- Stress ±172.5Mpa
- Displacement ≤50.8mm

2) Variables -10

(A1, A2, A3, A4, A5, A6, A7, A8, A9, A10)

A=Area of element

Table 1: Comparison of result-10bar truss problem

Solution From	Weight (N)	variables									
		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
Elperin	25,829.7	200.0	0.645	129.0	90.32	0.64	0.64	51.61	145.1	96.7	0.645
S. Rajeev & C.SKrishnamoorthy	22,653.5	206.4	0.645	151.6	103.2	0.64	0.64	54.8	129.0	132.2	0.645
Present study	23,071.1	209.2	0.645	90.32	170.9	0.64	0.64	64.5	126.3	129.4	0.645

5.3 Example for optimization of box girder.

After testing the simple problem of optimization, the present problem is connected to optimizer,the optimization of box girder for span 40m with carriage width of 7.5m, and M40 grade of concrete and Fe415 grade of steel is carried out and the following inputs are listed below.

Table2: Variableswhich are used in the optimization process.

Sl No	Description	Notation	Limits	
			Lower	Upper
1	Overall depth	X1	1m	3m
2	Depth of top flange	X2	0.2m	0.4m
3	Depth of bottom flange	X3	0.2m	0.4m
4	Thickness of web	X4	0.2m	0.4m
5	No of internal girder	X5	1	3

- No of constraints : 2

a) Stress : $\frac{\text{stress}}{\text{allowable stress}} - 1 < 0$

b) Deflection : $\frac{\text{total deflection}}{\text{permissible deflection}} - 1 < 0$

- No of individuals per subpopulation : 250
- Maximal number of generations : 250
- Generation gap : 0.8
- Selection function : Roulette wheel selection.
- Cross-over function : General multi-point crossover
- Mutation : Discrete mutation

VI. Results and discussion

6.1 Parametric study on effect of change in grade of concrete.

Table 3: Cost of girder for various grade of concrete for 40m span.

sl no	Grade of concrete	Optimum design variable						Cost
		Weight (kN)	X1 (m)	X2 (m)	X3 (m)	X4 (m)	X5 No.	(lakhs)
1	**M40**	**496.5**	**1.800**	**0.227**	**0.213**	**0.213**	**1**	□ **11.8**
2	M45	492.0	1.533	0.227	0.227	0.227	1	□ 12.29
3	M50	480.5	1.733	0.220	0.200	0.213	1	□ 13.2
4	M55	470.6	1.533	0.267	0.213	0.200	1	□ 14.3
5	M60	442.5	1.267	0.200	0.213	0.200	1	□ 14.9

- M40 grade of concrete is economic in cost and satisfy all checks in design, hence it is recommended to use for the study example.

6.2 Parametric study on effect of change in girder span for M40 grade of concrete.

Table 4: Optimum design variable for different span for M40 grade concrete.

Sl no	Span (m)	Optimum design variable					
		Weight (kN)	X1(m)	X2(m)	X3(m)	X4(m)	X5(No.)
1	10.00	199.07	1.13	0.23	0.29	0.23	1
2	20.00	221.25	1.27	0.20	0.21	0.20	1
3	30.00	392.77	1.27	0.31	0.24	0.21	1
4	40.00	496.51	1.80	0.23	0.21	0.21	1
5	50.00	734.91	1.93	0.23	0.21	0.28	2
6	60.00	856.23	1.80	0.24	0.23	0.25	2

- The weight of girder increases with increase in span of girder

Table 5: Optimum cost and variables for span 40 m and M40 grade of concrete

Initial Variables						
Weight(kN)	**X1(m)**	**X2(m)**	**X3(m)**	**X4(m)**	**X5(No.)**	**Cost(lakhs)**
681.99	2	0.3	0.3	0.3	1	□ 15.62
Optimum variables						
496.5	**1.8**	**0.22**	**0.21**	**0.21**	**1**	□ **11.8**

- The weight of box girder is decreased from 681.99kN to 496.5kN.
- The depth of girder, thickness of web, thickness of top and bottom flanges have been decreased.
- The number of internal girder remains same
- The cost of girder decreased from □ 15.62 to □ 11.8, i.e □ **3.82**lakhs reduced in optimization

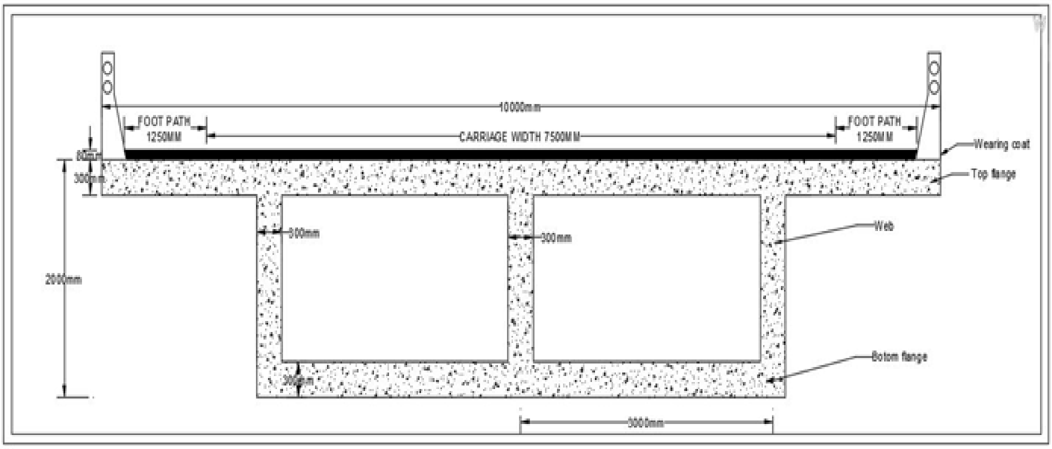

Fig 3: Cross section of box girder before optimization.

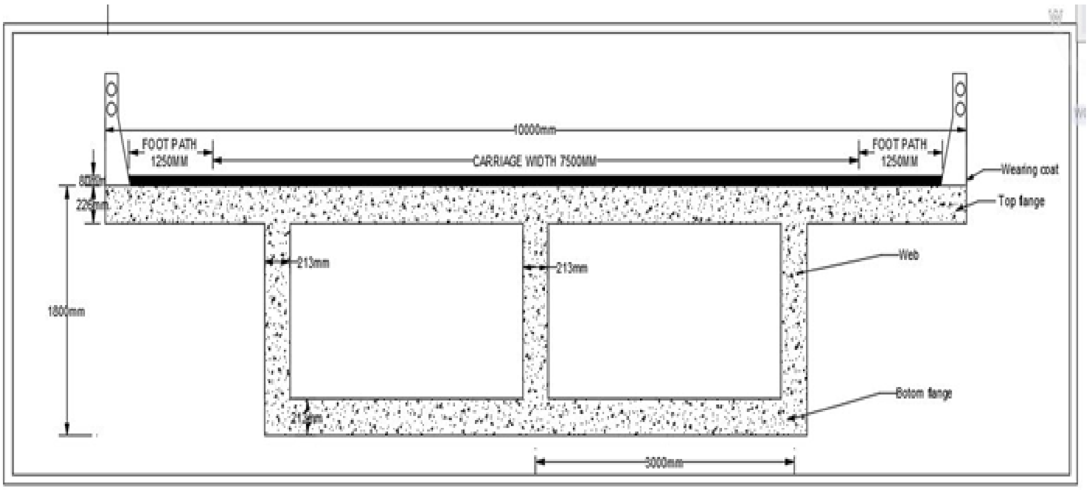

Fig 4: Cross section of box girder after optimization.

Table 6: The variation in pre-stressing force and number of tendons

sl no	Span (m)	Grade of concrete	Prestreesing force (kN)	No of tendons (27strands of 15.2dia)
Before optimization				
1	40	M40	19395	4
After optimization				
1	40	M40	18478	3

- After optimization design of PSC box girder using optimum section values is carried out and the following values are obtained
- The pre stressing force decreased from 19395kN to 18478kN.
- The no of tendons decreased from 4nos to 3nos.

VII. Conclusion

- Genetic algorithm can be satisfactorily applied for the optimization of box girder.
- Parametric study on the grade of concrete shows that total cost of structure increases with increase in the grade of concrete.
- Parametric study on the span of the bridge shows increase in the weight with increase in the span for the optimum section.
- The pre-stressing force is reduced for optimized section compared to the initial section considered.

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