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Cost Optimization Using GA for Structural Beams With Different and Conditions

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Abstract:- Beam elements are used both in load bearing structures and framed structures. To carry out an optimal design of reinforced concrete beam elements is an essential requirements to save cost. Optimization of reinforced concrete structural elements is a nonlinear problem. The problems are optimized for different types of loads and support conditions. The objective function is to minimize the total cost of the structural beam and design constraints for the beam are considered from the Indian Standard code. Breadth and depth were treated as continuous variables and the optimal design was carried out using Genetic Algorithm tool in MATLAB's software. Best fit solutions for various generations are obtained for different types of support conditions. Genetic algorithm sometimes gave infeasible results due to the random nature of search carried out by genetic algorithms.

I. INTRODUCTION

The optimization technique involves the choice of design variables to find the optimal solution satisfying the constraints with respect to geometry and behaviour. Optimum design of structures is to develop an "optimal solution" for the structural design under consideration. The total cost of the concrete structure is the sum of the costs of its constituent materials; including the cost of reinforcement. Feasible designs are obtained by optimization using numerical models of decision-making processes and satisfaction of specified objectives. In this paper genetic algorithms have been proposed for the design of an RCC rectangular beams. The design constrains is based on the IS: 456-2000 design guide lines. The optimization technique based on Genetic algorithm method has been modelled in MATLAB.

II. OPTIMIZATION PROBLEM

The optimization problem is classified on the basis of nature of equations with respect to design variables. The optimization problems can be linear or nonlinear based on the objective function. Genetic algorithm is an evolutionary algorithm based on the survival of the fittest. Genetic algorithm uses population and searches parents randomly from current population. It produces offspring using probability of Crossover and mutation. Cost optimization and different types of beams are taken (1) cantilever beam (2) simply supported beam (3) continuous beam and this also applied for two different loading conditions (a) point load and (b) uniformly distributed load.

The optimized beam has to satisfy the strength and durability condition of the code IS456:2000.

III. OBJECTIVE FUNCTION

The cost of the cantilever beam, simply supported and continuous beams is minimized without violating the constraints. The cost of the beams includes the costs of the concrete and the reinforcing steel. The total cost of the RC cantilever beam is

1. $F = C_c A_c L_b + C_s A_s L_s$
2. where
3. C_c - unit costs of concrete
4. A_c –Area of concrete
5. L_b - Length of the beam
6. C_s unit costs of reinforcement.
7. As –Area of Steel
8. Ls –Length of Steel rod

IV. DESIGN CONSTRAINTS

IS 456-2000 specifications for cantilever beams are as follows

1. deflections are within the permissible limits: for Cantilever beam

$$l/ \leq 7$$
$$l/d-7\leq 0$$

for Simply supported beam

$$l/ \leq 20$$
$$l/d-20\leq 0$$

for Continuous Beam

$$l/ \leq 26$$
$$l/d-26\leq 0$$

2. To ensure that a singly reinforced section the design moment, Mu was kept below the limiting value of the moment. According to IS 456-2000.

$$Mu\leq Mulimit$$
$$Mu-Mulimit\leq 0$$
$$Mu-0.138*fck*bd2\leq 0;$$
$$Mu-3.45*bd2\leq 0;$$

Where,
Characteristics strength of concrete =fck = 25 N/mm2

3. The maximum value of tension steel, Ast was limited as per IS 456-2000

$$Ast\leq 0.04bd$$
$$Ast-0.04bd\leq 0$$

4. The minimum area of tension steel is

$$Ast/bd\leq 0.85/fy$$

Characteristics strength of steel =fy = 415 N/mm2

5. The value of τc and design shear strength of concrete are taken from Table 19 and Table 20 IS 456-2000, But, table 19 is difficult to use when design parameter has to be
Computerized. For this purpose it is better to express the values by a formula. The semi-empirical formula used to derive table 19 is as follows

$$\tau c=0.85(\sqrt{}0.8fck)*(\sqrt{}1+5\beta-1)/6\beta$$
$$\beta=0.8fck/6.89pt$$
$$pt=100Ast/bd$$
$$(8.4*\sqrt{}Ast*bd-Vu/0.87*fy*d)-Asv/Sv\leq 0;$$

Maximum area of stirrups according to the IS 456: 2000 clause 26.5.1.6

$Asv/b*Sv\geq 0.4/0.87*f$; $Asv\geq 0.0011*b*Sv$ $S\leq 0.75d \text{ or } s\leq 300mm \text{ which ever is smaller}$.

V. ILLUSTRATIVE EXAMPLE

A. Cantilever Beam

This design example demonstrates the use of the program created to design an RCC cantilever beam of span 3000mm and subjected to a factored live load of 30kN/m. The grade of concrete chosen is M25 N/mm^2 and the grade of steel is Fe415. The cost of concrete is taken as Rs. 4500/- per m^3 and that of steel is Rs. 50/- per kg or Rs. 4, 00,000/- per cubic meter.

Cantilever beam (UDL full span)

Maximum bending moment Mumax$Mmax(at\ canter) = \frac{WL^2}{2} = 135 * 10^6$

Maximum shear force Vu $Vu = WL = 90 * 10^6$

Cantilever beam (Point load at free end)

Maximum bending moment Mumax$Mmax(at\ canter) = WL = 90 * 10^6$

Maximum shear force Vu $Vu = W = 30 * 10^6$

B. Simply Supported Beam

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This design example demonstrates the use of the program created to design an RCC simple supported beam of span 6000mm and subjected to a factored live load of 30kN/m. The grade of concrete chosen is M25 N/mm^2 and the grade of steel is Fe415. The cost of concrete is taken as Rs. 4500/- per m^3 and that of steel is Rs. 50/- per kg or Rs. 4, 00,000/- per cubic meter.

Simply supported beam (UDL full span)

Maximum bending moment Mumax $Mmax(at\ canter) = \frac{Wl^2}{8} = 135 * 10^6$

Maximum shear force Vu $Vu = \frac{wl}{2} = 90 * 10^6$

Simply supported beam (Point load at canter)

Maximum bending moment Mumax $Mmax(at\ canter) = \frac{Wl}{4} = 45 * 10^6$

Maximum shear force Vu $Vu = \frac{w}{2} = 30 * 10^6$

C. Continuous Beam

This design example demonstrates the use of the program created to design an RCC Continuous beam of span 9000mm and subjected to a factored live load of 30kN/m. The grade of concrete chosen is M25 N/mm^2 and the grade of steel is Fe415. The cost of concrete is taken as Rs. 4500/- per m^3 and that of steel is Rs. 50/- per kg or Rs. 4, 00,000/- per cubic meter.

Continuous beam (Two equal spans & UDL full spans)

Maximum bending moment Mumax $Mmax = \frac{WL^2}{8} = 303.75 * 10^6$

$$or\ \frac{9WL^2}{128}\left(at\ \frac{3L}{8}\ from\ M1\right) = 170.85 * 10^6$$

Maximum shear force Vu $Vu = \frac{5WL}{8} = 168.75 * 10^6$

Continuous beam (Point load on mid span of two spans)

Maximum bending moment Mumax

$$Mmax(at\ canter) = -\frac{3WL}{16} = -50 * 10^6$$

Maximum shear force Vu $Vu = \frac{11W}{16} = 20.625 * 10^6$

VI. RESULTS

Type of beam	Span of the beam (mm)	Breadth b(mm)	Depth d(mm)	Area of reinforcement Ast(mm2)	Area of stirrups Asv(mm2)	Spacing of stirrups Sv(mm)	Total cost In Rupees
Cantilever (UDL)	3000	450.613	622.081	786.512	594.354	294.940	5400.9132
Cantilever (PL)	3000	252.359	688.477	1407.98	400.014	298.234	4490.6814
Simply supported(UDL)	6000	448.960	896.441	723.921	843.823	211.881	14587.1847
Simply supported(PL)	6000	452.876	869.652	607.253	789.359	186.034	13947.8729
Continuous (UDL)	9000	399.748	674.978	400.021	961.875	297.789	15775.2781

Fig.1. Cantilever UDL solution

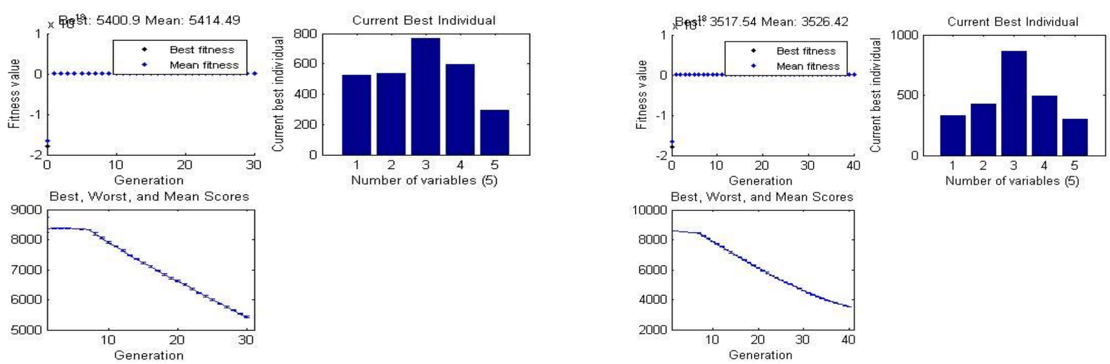


Fig.2. Cantilever Point load solution

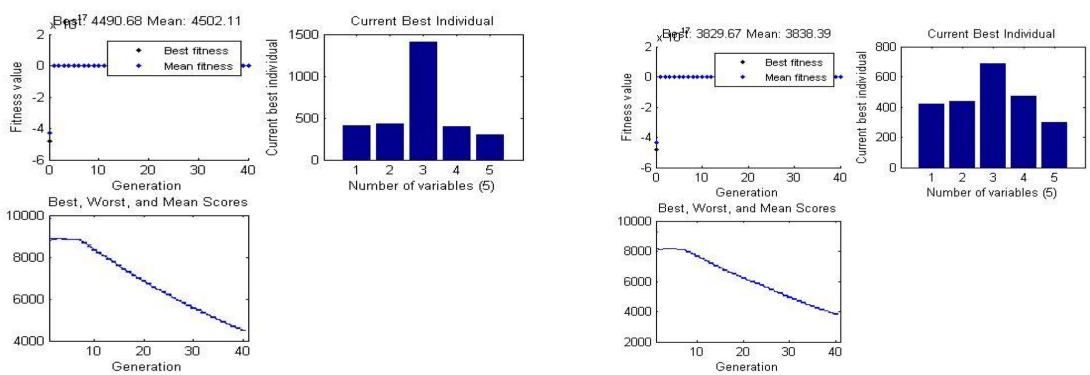


Fig.3. Simply supported UDL solution

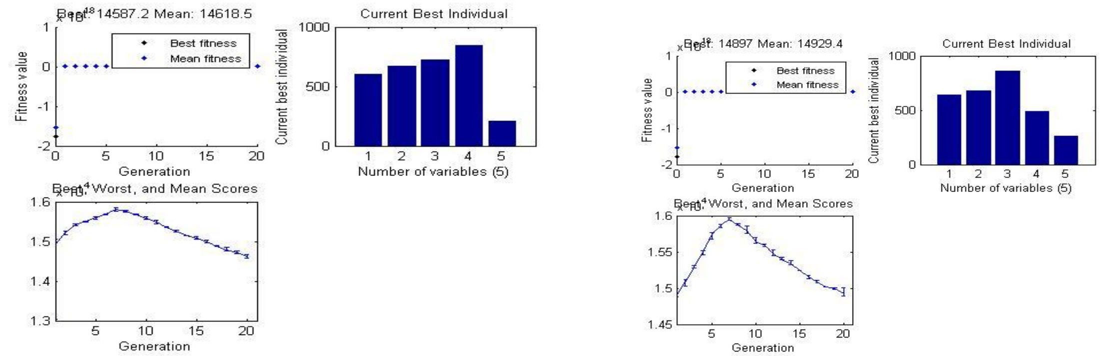


Fig.4. Simply supported Point load solution

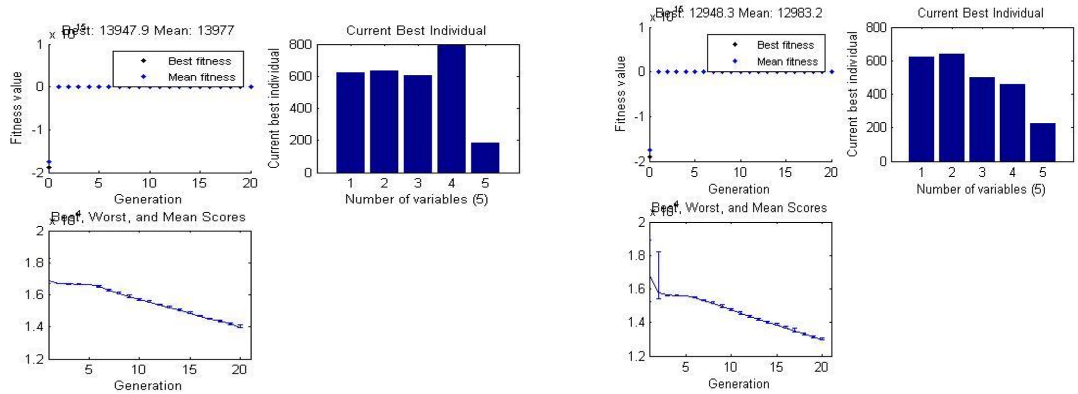
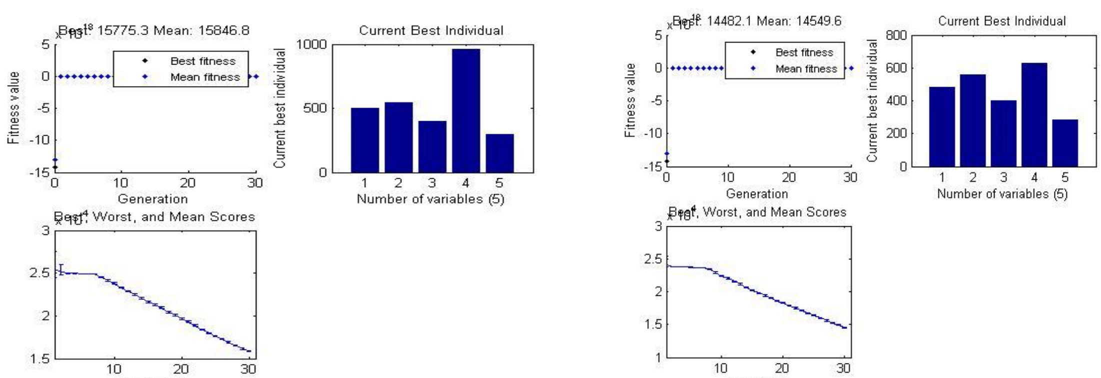


Fig.5. Continues beam UDL solution



VII. CONCLUSIONS

Genetic algorithm could be effectively used in optimizing cost of structural elements. Genetic algorithm based design of beams gave reasonable results, satisfying all constraints. This method has the advantage that the cost of concrete and steel can be incorporated into the design. Optimal cost of beams obtained satisfying all the constrains from IS 456:2000 code. This will help in obtaining reasonable sections and steel based on the cost. Other constraints can also be easily applied into the design, making the design to suit various requirements. The values obtained from the GA program are representative values only. The choice of practical values are left to the decision of the design engineers.

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