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Discrete Optimisation of One way Slab using Genetic Algorithm

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Abstract*: Optimising most structural systems used in practice requires considering design variables as discrete quantities. The paper presents the Cost optimisation of One Way Slab. The variables used in this research are discrete variables. The optimisation techniques in general enable designers to find the best design for the structure under consideration. The best design of a structure means the most economic structure without impairing the functional purposes the structure is supposed to serve. In this particular case, the principal design objective is to minimise the total cost of a structure. The resulting structure, however, should not only be marked with a low price but also comply with all strength and serviceability requirements for a given level of the applied load as per IS: 456-2000. Total cost includes cost of concrete, cost of steel and cost of form work are considered. Heuristic techniques, namely the Genetic Algorithm was carried out in this research. Genetic algorithms (GA) belong to the family of evolutionary algorithms (EA). Since the adjustment of parameters in a genetic algorithm (e.g., population size, crossover and mutation rates, and maximum number of generations) is a significant problem for any application, we present our own methodology to deal with this problem.*

Keywords*: Optimisation, Genetic Algorithm, Matlab, One Way Slab.*

I. INTRODUCTION

Optimum design of structures has been the topic of many studies in the field of structural design. A designer’s goal is to develop an “optimal solution” for the structural design under consideration. An optimal solution normally implies the economic structure without impairing the functional purposes the structure is supposed to serve. The total cost of the concrete structure is the sum of the costs of its constituent materials; these constituent materials are at least: concrete, steel and framework, *(Sarma and Adeli, 1998)*.

As there are an infinite number of possible slab dimensions, reinforcement ratios and pre stressing forces that yield the same moment of resistance, it becomes difficult to achieve the least-cost design by conventional iterative methods. It was shown that even for a simple and well-defined RC structure of a small garage; the designs proposed by experienced design engineers can be very different. In such a situation, an optimisation procedure can help designers to find the best design or at least, a good design among different possible designs.

There are some characteristics of RC structures, which make design optimisation of these structures distinctly different from other structures. Several cost items including the cost of concrete and reinforcement, influence the cost of RC structures. Therefore, in case of RC structures, the minimum weight design is not necessarily the same as the minimum cost design. In fact, for RC structures the optimum cost design is a compromise between the consumption of concrete, reinforcement, which minimises the total cost of the structure and satisfies the design requirements. In the design optimisation of RC structures the cross-sectional dimensions of elements and detailing of reinforcement, e.g. size and number of steel bars, need to be determined. Consequently, the number of design parameters that need to be optimised for a RC structure can be larger than that for a steel structure. Also cracking and durability requirements are two characteristic properties of RC structures; these increase the number of design constraints of the optimisation problem of RC structures. *(Sahab, 2002)*

II. GENETIC ALGORITHM AS AN OPTIMISATION TECHNIQUE

The genetic algorithm (GA) is a heuristic search technique based on the mechanics of natural selection developed by John Holland. The genetic algorithm is a highly parallel mathematical algorithm that transforms a set (population) of individual mathematical objects (typically fixed- length character strings patterned after chromosome strings), each with an associated fitness value, into a new population (i.e. the next generation) using operations patterned after the Darwinian principle of reproduction and survival of the fittest and after naturally occurring genetic operations.

- Genetic algorithms use a population of points at a time in contrast to the single-point approach by the traditional optimization methods. That means, at a given time, Genetic algorithms process a number of designs.
- Genetic algorithms do not require problem-specific knowledge to carry out a search. For instance, calculus-based search algorithms use derivative information to carry out a search. In contrast to this, Genetic algorithm are in different to problem-specific information.

- Genetic algorithms work on coded design variables, which are finite length strings. These strings represent artificial chromosomes. Every character in the string is an artificial gene. Genetic algorithms process successive populations of these artificial chromosomes in successive generations.
- Genetic algorithms use randomized operators in place of the usual deterministic ones.

III. PROBLEM FORMULATION

A large number of papers have been published on optimisation of structures. The great majority deals with minimum weight design or academic examples. For structural optimisation algorithms to find widespread usage among practicing engineering ,they must be formulated as cost optimisation and applied to realistic structures subjected to the actual constraints of commonly used design codes such as the Indian code (IS 456:2000).

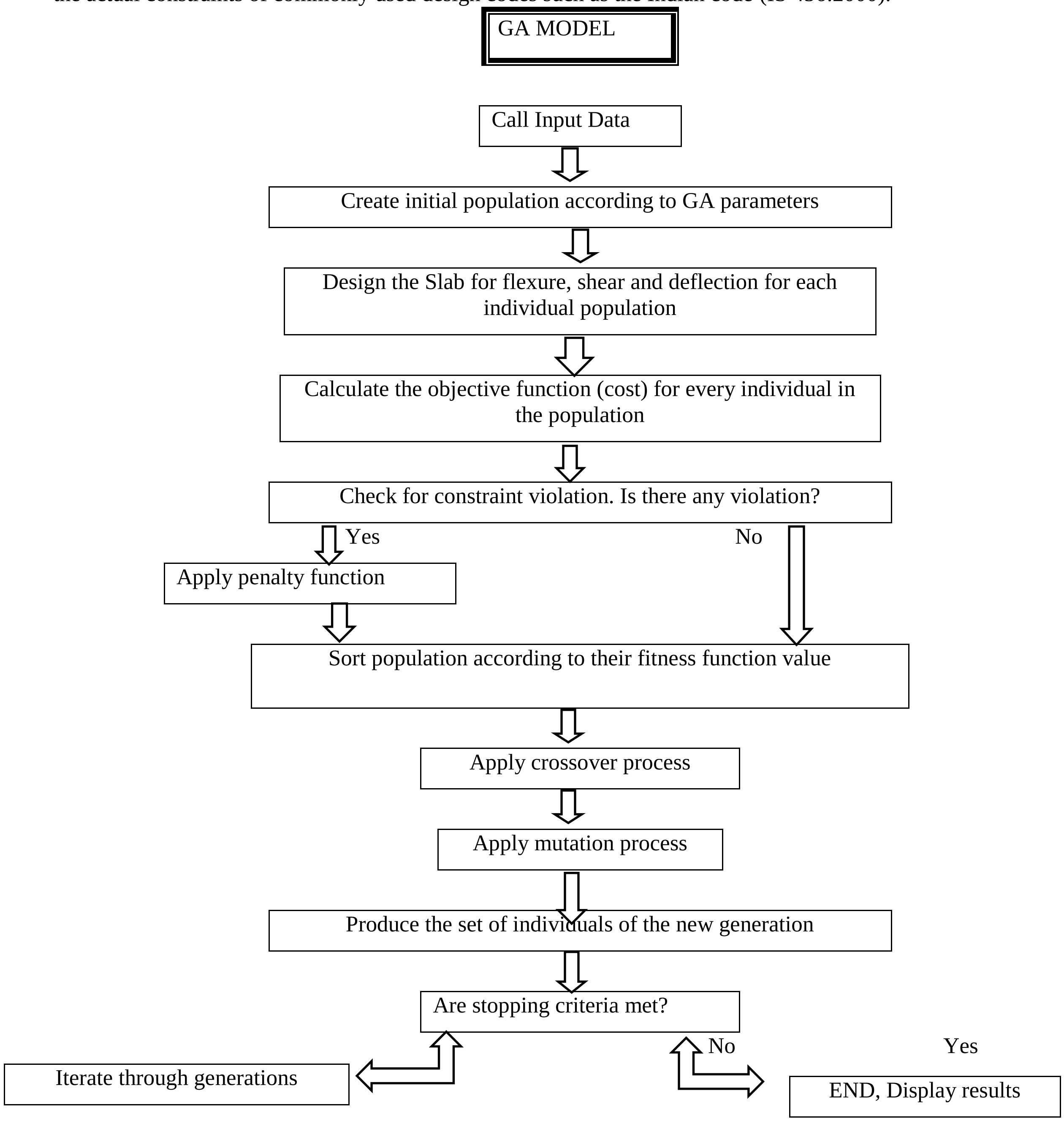

Figure 1: Flow chart representing Genetic Algorithm

Therefore, in present research, a general formulation is presented for cost optimisation of one way RC slabs subjected to all the constraints of the IS 456:2000. The problem is formulated as a mixed integer-discrete variable optimisation problem.

Design variables for slab:

- Thickness of slab
- Bar spacing
- Main Reinforcement bar diameter

Keeping the above design variables in concern, optimum cost would be calculated for RC slabs. A flow chart has been created which describes the way, the genetic algorithm works in present thesis.

A. Objectives

The relative objective of the research are further explained as follow

1. Discrete Optimisation of One-way slab with respect to cost.
2. For all research work, multiple grade of concrete and steel will be used according to codal provision IS 456:2000

B. Design of one way slab

The general form of an optimisation is as follows

1.	Given	-	Constant parameters
2.	Find	-	Design variables
3.	Minimise	-	Objective function
4.	Satisfy	-	Design constraint

B.1. Constant parameter

The constant parameters specified prior to the solution of the optimisation problem include following:

Cost of concrete per m^3 for M20	=	C	=	Rs 4500/m^3
Cost of steel per m^3 for Fe415	=	S	=	Rs 353250/m^3
Cost of concrete per m^3 for M25	=	C	=	Rs 5000/m^3
Cost of steel per m^3 for Fe500	=	S	=	Rs 392500/m^3
Cost of Formwork per m^2	=	F	=	Rs 100/m^2
Breadth of slab	=	B	=	3 m, 3.5 m, 4 m, 4.5 m,5 m
Live load	=			3 kN/m^2, 5 kN/m^2, 7 kN/m^2
Characteristics strength of steel	=	f_y	=	415 KN/m^2, 500 KN/m^2
Characteristics strength of concrete	=	f_{ck}	=	20 KN/m^2, 25 KN/m^2

B.2. Design variables

Depth of slab	=	d	=	x (1)
Spacing of main reinforcement	=	S_v	=	x (2)
Diameter of reinforcement bar	=			x (3)

Design variable vector

$$X = \{x_1\ x_2\ x_3\} = \{\ depth\ spacing\ diameter\ \}$$

B.3. Objective function

The objective function to be minimised,

$$f(x) = \ costconcrete\left[width * x(1) * breadth - \left(\frac{\pi}{4} * x(3)^2 * \left(\frac{width}{x(2)} + 1\right) * breadth\right) + 0.0012 * width * x(1)\ \right)\Big] + coststeel[\frac{\pi}{4} * x(3)^2 * \left(\frac{width}{x(2)} + 1\right) * breadth + 0.0012 * width * x(1)] + costformwork(breadth * x(1))$$

B.4. Constraints

a. Constraint on flexural strength

The factored moment must be equal to or less than permissible moment.

$$constraint(1) = \ moment/[0.87f_y\left(\frac{\pi}{4} * x(3)^2 * \left(\frac{width}{x(2)} + 1\right)\right) * d * (1 - \frac{(\frac{\pi}{4}*x(3)^2*\left(\frac{width}{x(2)}+1\right)))f_y}{width*x(1)*f_{ck}})] - 1 \leq 0$$

b. Constraint on shear strength

$$constraint(2) = \frac{shear}{width*x(1)*k*7.66*\left(\frac{x(3)^2}{width*x(1)}*\left(\frac{width}{x(2)}+1\right)\right)} - 1 \leq 0$$

$$constraint(3) = \frac{shear}{width*x(1)*0.5*\tau_{c,max}} - 1 \leq 0$$

c. Constraint for Spacing of Main Reinforcement

$$constraint(4) = x(2)/300 - 1\ \leq 0$$

$constraint(5) = x(2)/3 * x(1) - 1 \le 0$

d. Constraint for Diameter of bar

$$constraint(6) = x(3) * \frac{8}{x(1)} - 1 \le 0$$

$$constraint(7) = x(3)/18 - 1 \le 0$$

e. Minimum Reinforcement

$$constraint(8) = 0.0012 * width * \frac{x(1)}{.7853 * \left((x(3))^2\right) * \left(\left(\frac{width}{x(2)}\right) + 1\right)} - 1 \le 0$$

$$constraint(9) = \frac{x(3)}{0.7853} * \frac{1000}{0.7853 * \left(\left(\frac{width}{x(2)}\right) + 1\right)} - 1 \le 0$$

IV. RESULTS

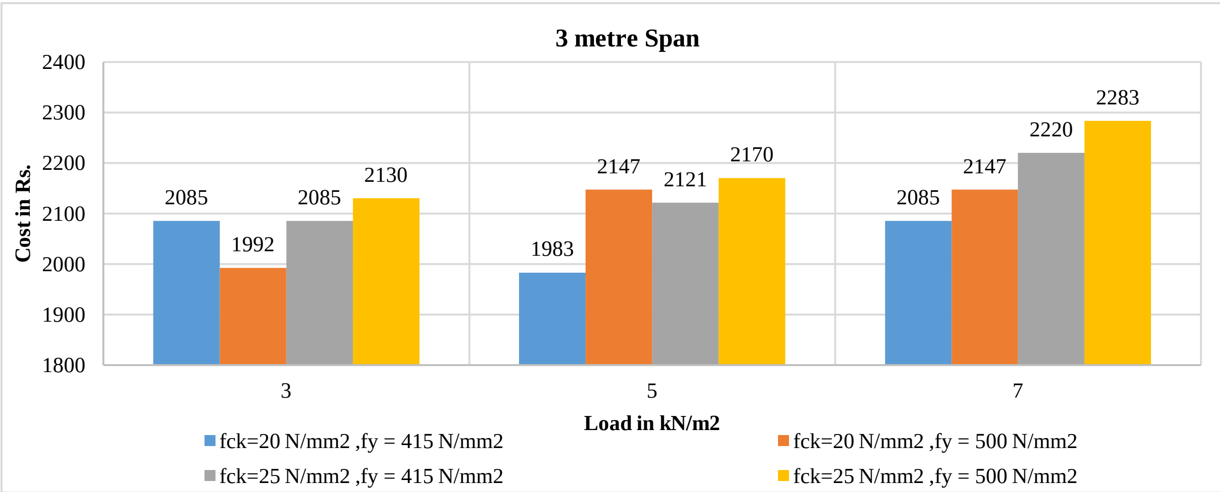

Figure 2: Graph b/w Cost and Load for 3 metre span

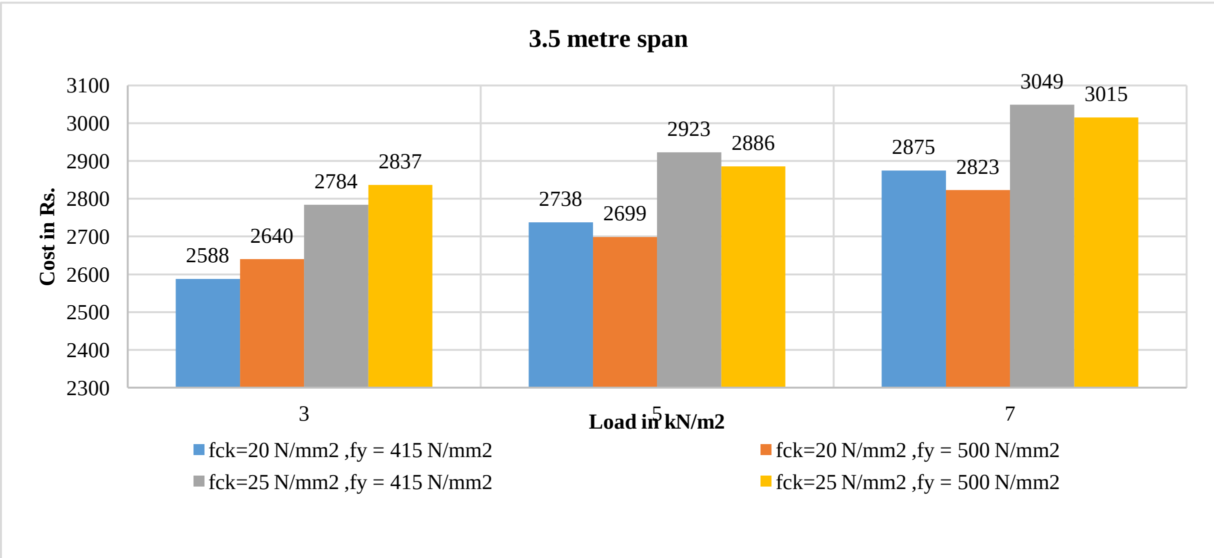

Figure 3: Graph b/w Cost and Load for 3 metre span

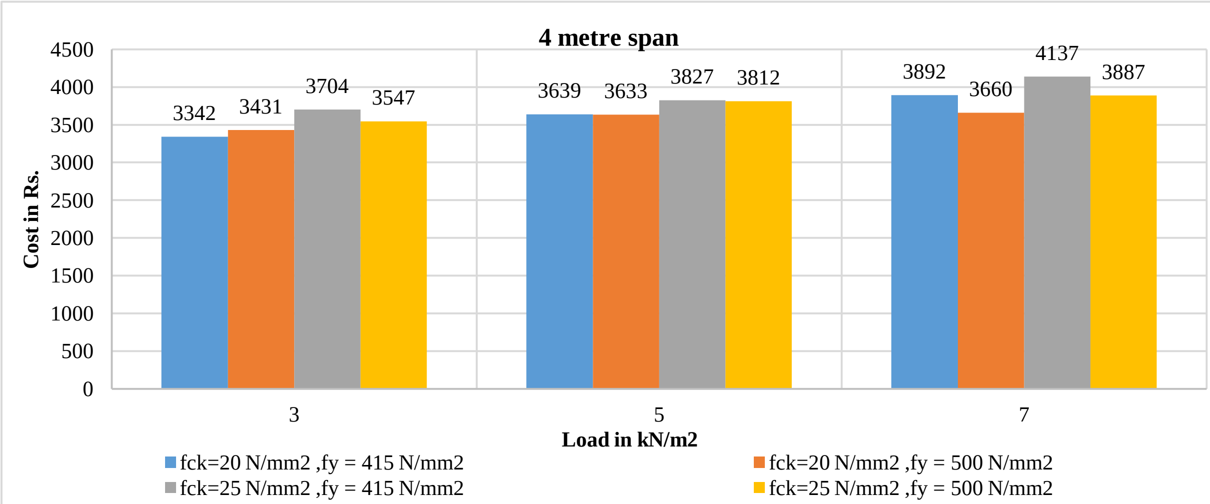

Figure 4: Graph b/w Cost and Load for 4 metre span

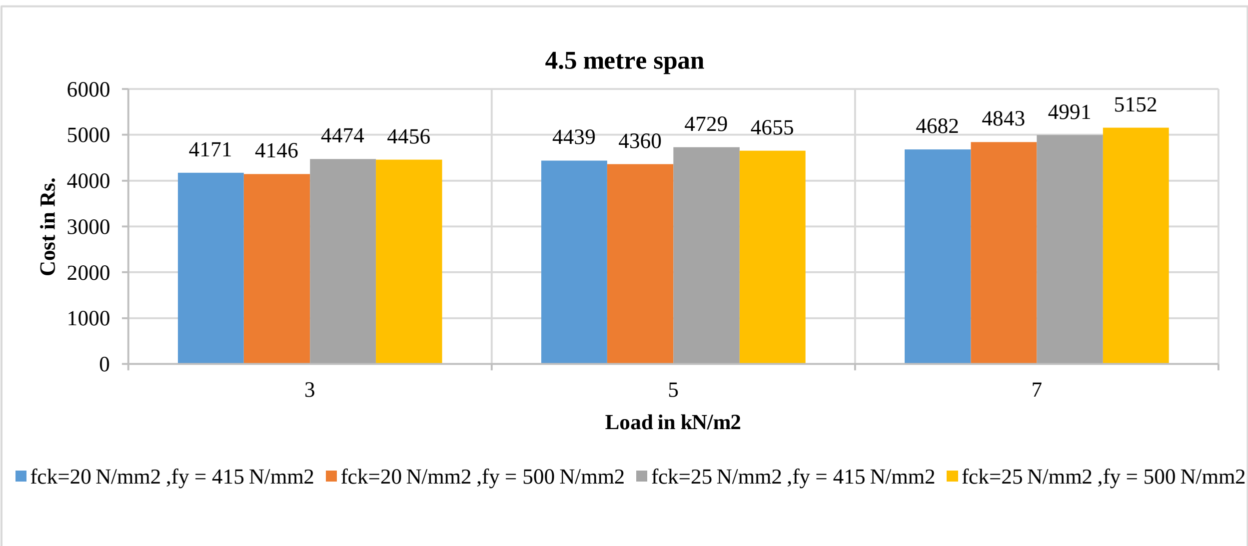

Figure 5: Graph b/w Cost and Load for 4.5 metre span

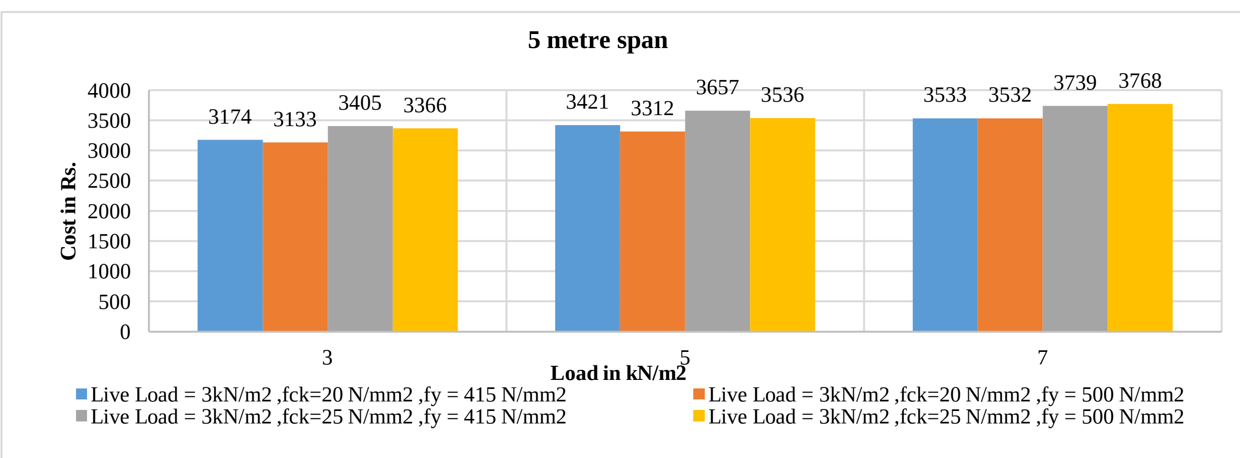

Figure 6: Graph b/w Cost and Load for5 metre span

V. CONCLUSIONS

1. Having l/d ratio =29-30, gives us the optimum cost for our considerations.
2. M20 and fy 500 to be used for the optimum results.
3. It is not always true that higher grade will always results in minimum cost.

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