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COST EFFECTIVE DESIGN OF RC T-BEAM EMPLOYING GENETIC ALGORITHM

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ABSTRACT

As most of the work of optimisation is done by considering weight as objective function with the assumption that minimum cost will come from minimum weight, but practically it is not so. The paper presents the optimisation of t-beam taking cost as objective function. The variables used in this research are discrete variables. The optimisation techniques enable designers to find the perfect design for the structure. The perfect design of a structure means the most economic structure without impairing the purposes for which it is made. In this case, the design objective is to minimise the total cost of a structure. The ensuing structure, nevertheless, should not only be marked with a low cost but also obey with a working strength requirements for the given applied load as per is: 456-2000. These elements are designed according to the requirements of the is 456:2000 code. Total cost includes cost of concrete, steel and form work are considered. Genetic algorithm which is a type of heuristic techniques was carried out in this research. Genetic algorithm belongs to the family of evolutionary algorithms. Genetic algorithm is an iterative procedure that is driven from the 'survival of the fittest' principle of darwinian theory of natural evolution. Since the adjustment of factors in a genetic algorithm (e.g., population size, crossover, and maximum number of generations) is a significant problem for any application, we have applied our own methodology to deal with this problem.

Keywords: optimisation, genetic algorithm, t-beam, matlab.

1. INTRODUCTION

Optimum design of structures has been the theme of many studies in the field of structural design. An engineer's objective is to develop an "optimum solution" for the structural design under concern. An ideal solution normally implies the economic structure without impairing the functional purposes the structure is supposed to serve. The overall 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 vast number of promising beam dimensions and reinforcement ratios that return the same moment of resistance, it becomes challenging to attain the least-cost design by conventional iterative approaches. 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 catch the best design otherwise at least, a good design amongst different likely designs. Numerous approaches have been established and are in usage for design optimisation of structural systems. Mathematical programming methods are used to attain ideal solutions. Most of the methods adopt that the design variables are continuous, but it is not mandatory that it is always true. In maximum practical problems in engineering design, the design variables are distinct. Availability of apparatuses in standard sizes and restrictions due to construction and manufacturing practices are the main reason behind it. To handle the discrete nature of design variables a few set of rules have been developed. Optimisation techniques that use discrete variables are more coherent ones, as every aspirant design evaluated is a practically achievable one. It is not compulsory that all design variables are continuous, where all the designs evaluated during the process of optimisation may not be practically possible even though they are mathematically possible. This problem is very significant in solving practical problems of design optimisation.

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2. GENETIC ALGORITHMS AS AN OPTIMISATION TECHNIQUE

John Holland (1975) defines that genetic algorithm is a extremely similar mathematical algorithm that transmutes a set of distinct mathematical things (usually fixed-length character strings spotted after chromosome strings), each through a related fitness value, into a new population (i.e. the next generation) by operations patterned after the Darwinian principle of reproduction and survival of the fittest and after naturally happening genetic operations. Genetic algorithm vary from old-style optimisation algorithms in numerous means. A few are listed here.

- Genetic algorithms don't entail problem-specific acquaintance to bring out a hunt.
- Genetic algorithms effort on coded design variables, which are restricted length strings. These strings characterize fake DNAs. Every character in the string is an artificial gene.
- Genetic algorithms practise a populace of opinions at a time in contrast to the single-point tactic by the outmoded optimisation approaches. That means, at a given time, Genetic algorithms do a number of designs.
- Genetic algorithms use random operatives instead of the customary deterministic ones.

3. PROBLEM FORMULATION

Numerous numbers of papers have been published on the optimisation of structures. Among all, maximum deals with minimum weight design or academic cases. For structural optimisation algorithms to find widespread usage among practicing engineering ,they must be expressed as cost optimisation and realistic structures subjected to the actual constraints of commonly used design codes such as the Indian code(IS 456:2000). Therefore, in present thesis, a general formulation is presented for cost optimisation of one way RC slabs and T-beam with simply supported end condition and are subjected to all the constraints of the IS 456:2000. The problem is framed as a mixed integer-discrete variable optimisation problem.

Design variables for T-beam:

- Width of web
- Effective depth
- Area of main reinforcement
- Area of shear reinforcement

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

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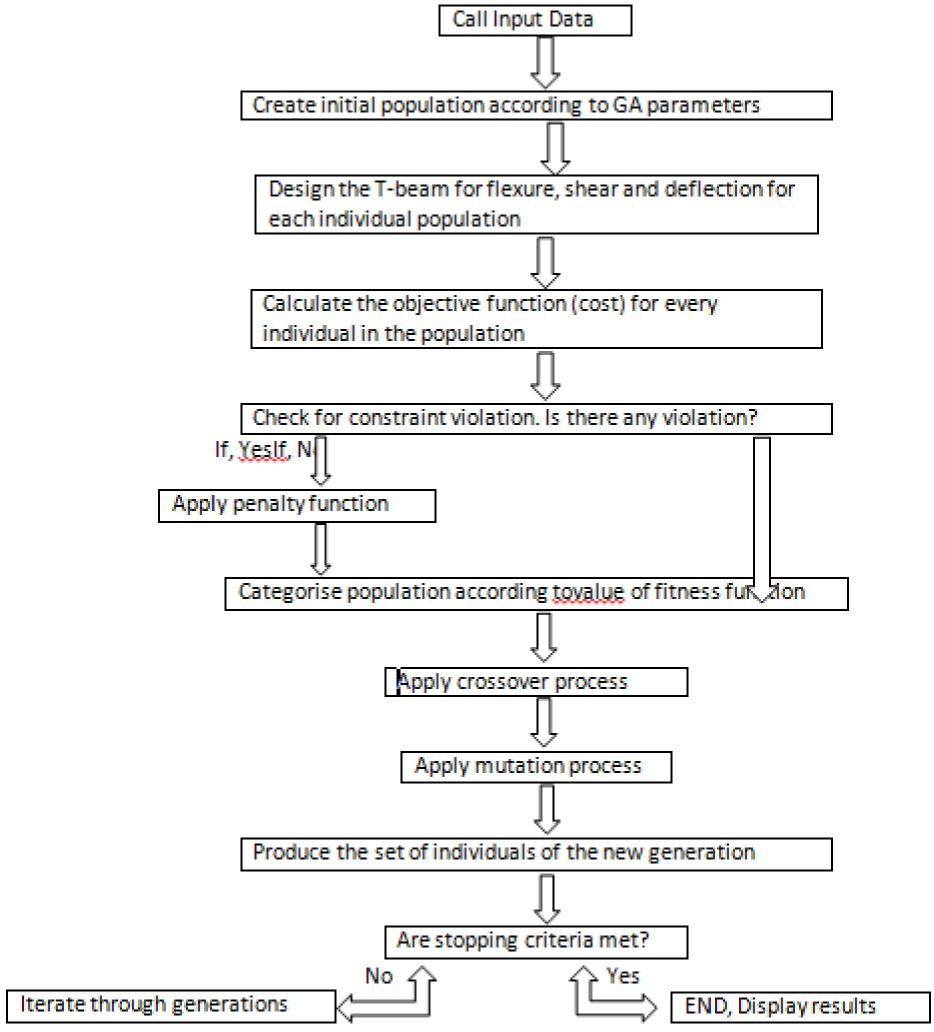

Figure 1: Flow chart representing Genetic Algorithm

Objectives

The relative objective of the research:

Optimization of T-beam with respect to cost.

For our research work, multiple grade of concrete and steel will be used according to codal provision IS 456:2000

Singly Reinforced T-Beam

The standardprocedure of an optimisation problem is as follows:

Given	-	Constant parameters
Find	-	Design variables
Minimise	-	Objective function
Satisfy	-	Design constraint

Constant Parameters

Following are the parameter taken for the optimisation problem:

Cost of concrete per $m^3$for M20	=	C	=	Rs 4,500/m^3
Cost of steel per $m^3$for Fe415	=	S	=	Rs 45/kg or 3, 53,250/m^3
Cost of concrete per m^3 for M25	=	C	=	Rs 5,000/m^3

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Cost of steel per m^3 for Fe500	=	S	=	Rs 50/kg or 3, 92,500/m^3
Cost of Formwork per m^2	=	F	=	Rs 100/m^2
Span of the beam	=	L	=	4m, 6m, 8m, 10m, and 12m
Factored load	=	Wu	=	40 kN/m, 60 kN/m
Depth of flange	=	D_f	=	100 mm, 200 mm
Yield strength of steel	=	f_y	=	415 N/mm^2, 500 N/mm^2
Characteristics strength of concrete	=	f_{ck}	=	20 N/mm^2, 25 N/mm^2

Design variables

Width of beam (rib)	=	b_w	=	x_1
Effective depth of beam	=	d	=	x_2
Main reinforcement	=	A_{st}	=	x_3
Shear reinforcement	=	A_{sv}	=	x_4

The design variable vector
X $=\{x_1 x_2 x_3 x_4\} = \{b_w\ d\ \ A_{st} A_{sv}\ \}$

Objective function

The objective function to be minimised

$$f(x) = C[(b_w(D - D_f) + b_f * D_f) * L - ((A_{st} * L) + (A_{sv}(2b_w + 2d)))] + S[A_{st}(L) + (A_{sv}(2b_w + 2d))] + F(b_w + 2(D - D_f) + (b_f - b_w))(L)$$

$$f(x) = C\left[\left(x_1 * (x_2 + d' - D_f) + (\frac{L}{6} + x_1 + 6D_f) * D_f\right) * L - (x_3\ * L + x_4 * (2 * x_1 + 2 * x_2)]\right. \\ \left. + S[x_3 * L + x_4 * (2 * x_1 + 2 * x_2))\right] \\ + F\left(x_1 + 2(x_2 + d' - D_f) + \left(\frac{L}{6} + x_1 + 6D_f - x_1\right) + 2 * D_f\right) * (L)$$

Constraints

Constraint on flexural strength

$$constraint(1) = M_u - [0.87 f_y x(3) x(2)(1 - \frac{x(3) f_y}{(\frac{L}{6} + x(1) + 6D_f) x(2) f_{ck}})] \leq 0$$

Constraint on shear strength

$$constraint(2) = V_{ud} - (8.314\sqrt{x(1)x(2)x(3)} + (\frac{0.87 f_y x(4) x(2) x(4)}{785.39 * d^2})) \leq 0$$

Constraint for minimum shear reinforcement

$$constraint(3) = \frac{0.4x(1)x(5)}{0.87 f_y} - x(4) \leq 0$$

Constraint for maximum shear reinforcement

$$constraint(4) = V_{ud} + W_u(\frac{b_s}{2} + x(2)) - \tau_{ucmax} x(1) x(2)\ \leq 0$$

Constraint for minimum area of tension reinforcement

$$constraint(5) = \frac{0.85x(1)x(2)}{f_y} - x(3) \leq 0$$

Constraint for maximum area of tension reinforcement

$$constraint(6) = x(3) - 0.04x(1)(x(2) + d') \leq 0$$

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Constraint for spacing of shear reinforcement

$$constraint(7) = \frac{785.39 * d^2}{x(4)} - 0.75x(2) \leq 0$$

$$constraint(8) = \frac{785.39 * d^2}{x(4)} - 300 \leq 0$$

Constraint for serviceability requirement

$$constraint(9) = \frac{L}{x(2)} - 0.8K \leq 0$$

Geometrical constraint (for width and depth)

$$constraint(10) = lb\ of\ x(1) - x(1) \leq 0$$
$$constraint(11) = x(1) - ub\ of\ x(1) \leq 0$$
$$constraint(12) = lb\ of\ x(2) - x(2) \leq 0$$
$$constraint(13) = x(2) - ub\ of\ x(2) \leq 0$$

4. RESULTS

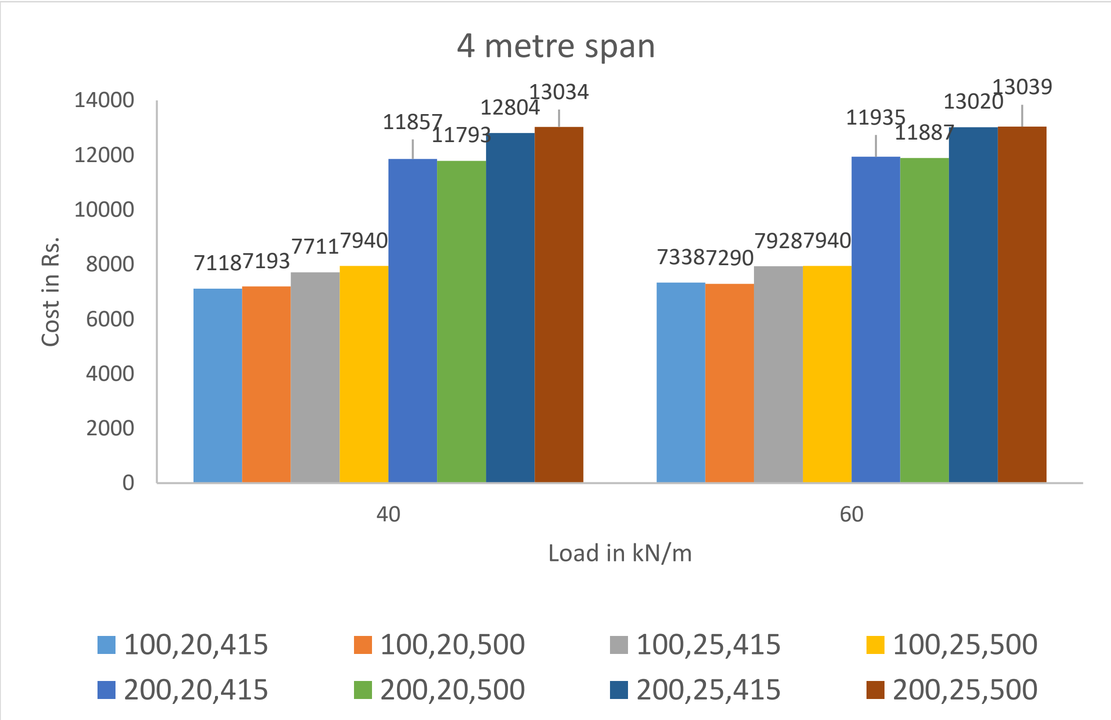

Figure 2: Cost vs. Load graph of Tbeam for 4 metre span

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Impact Factor: 5.164
CODEN: IJESS7

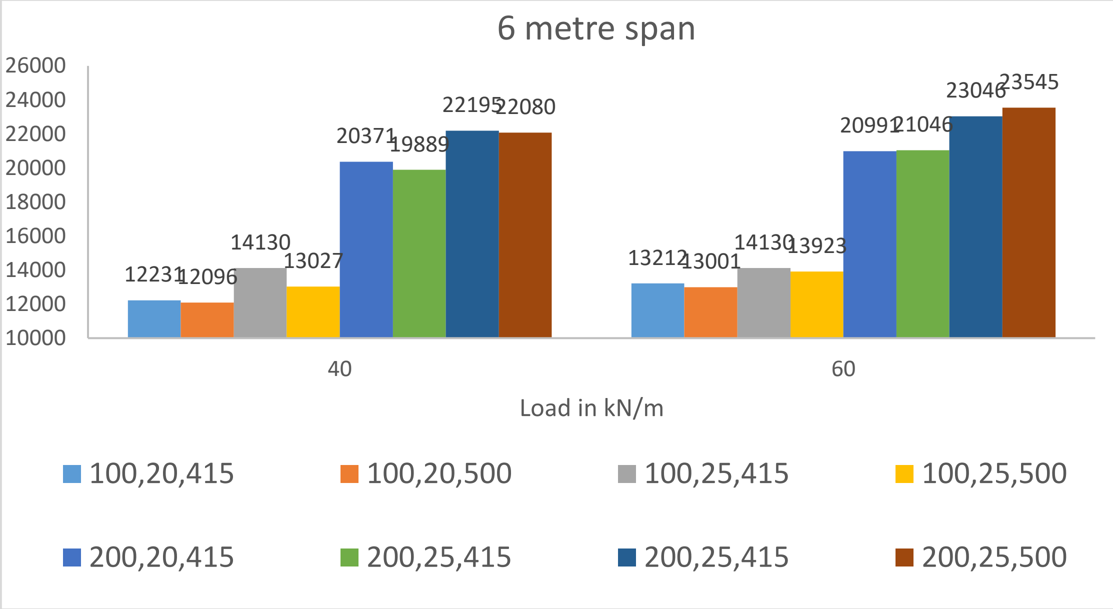

Figure 3: Cost vs. Load graph of Tbeam for 6 metre span

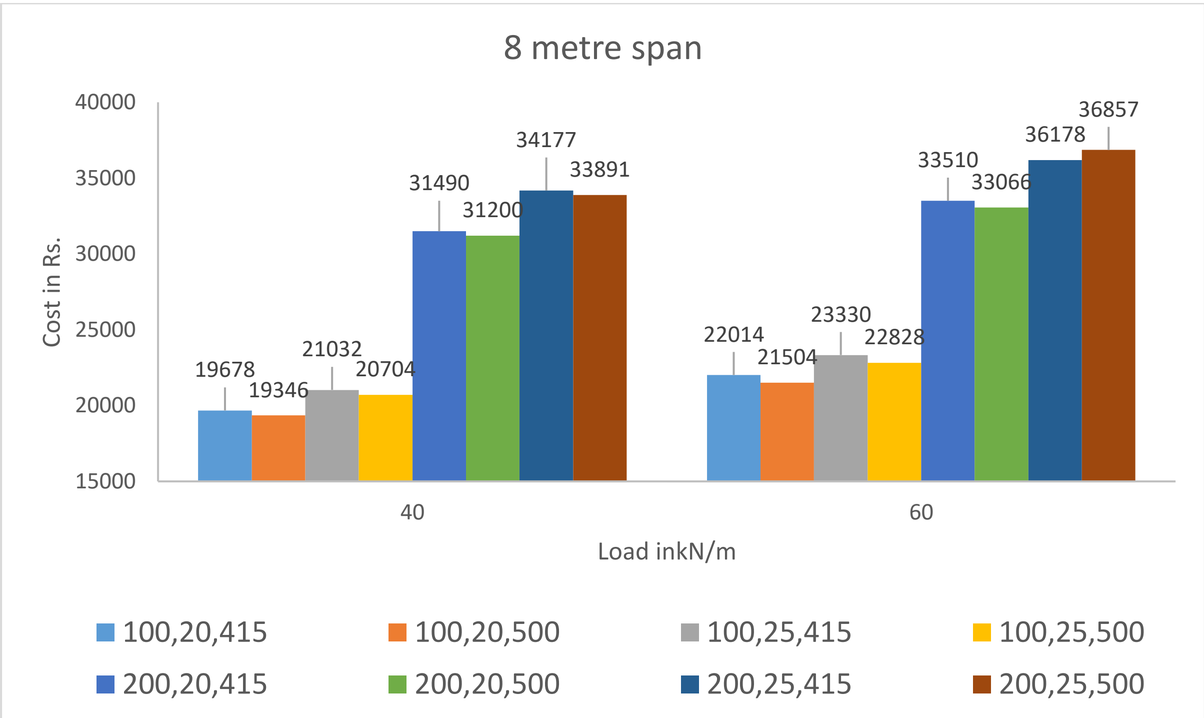

Figure 4: Cost vs. Load graph of Tbeam for 8 metre span

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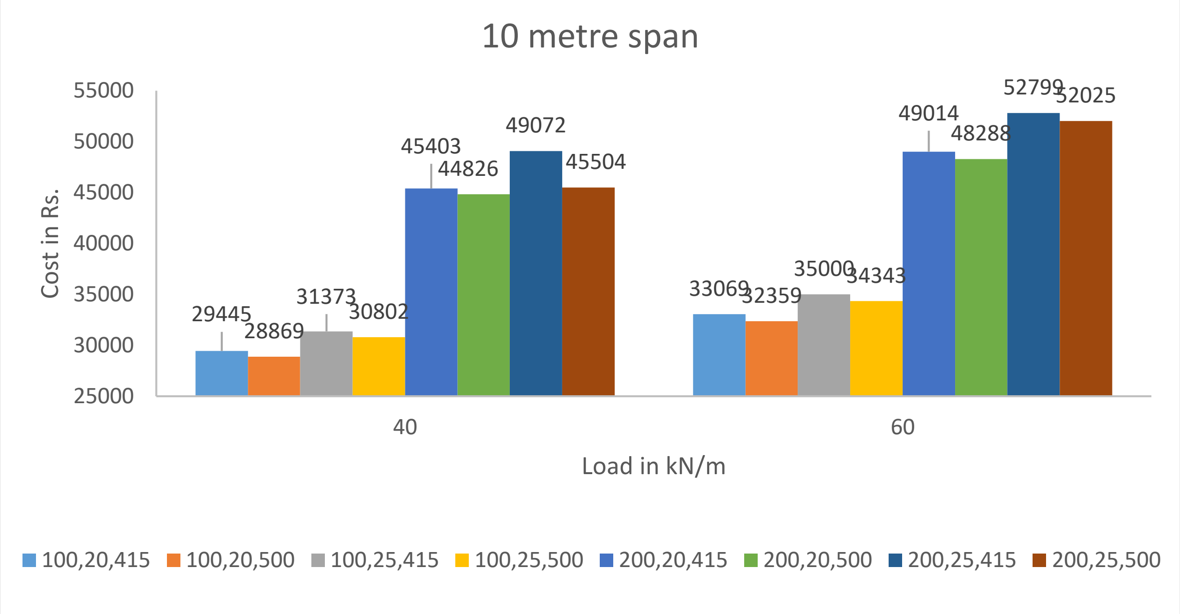

Figure 5: Cost vs. Load graph of Tbeam for 10 metre span

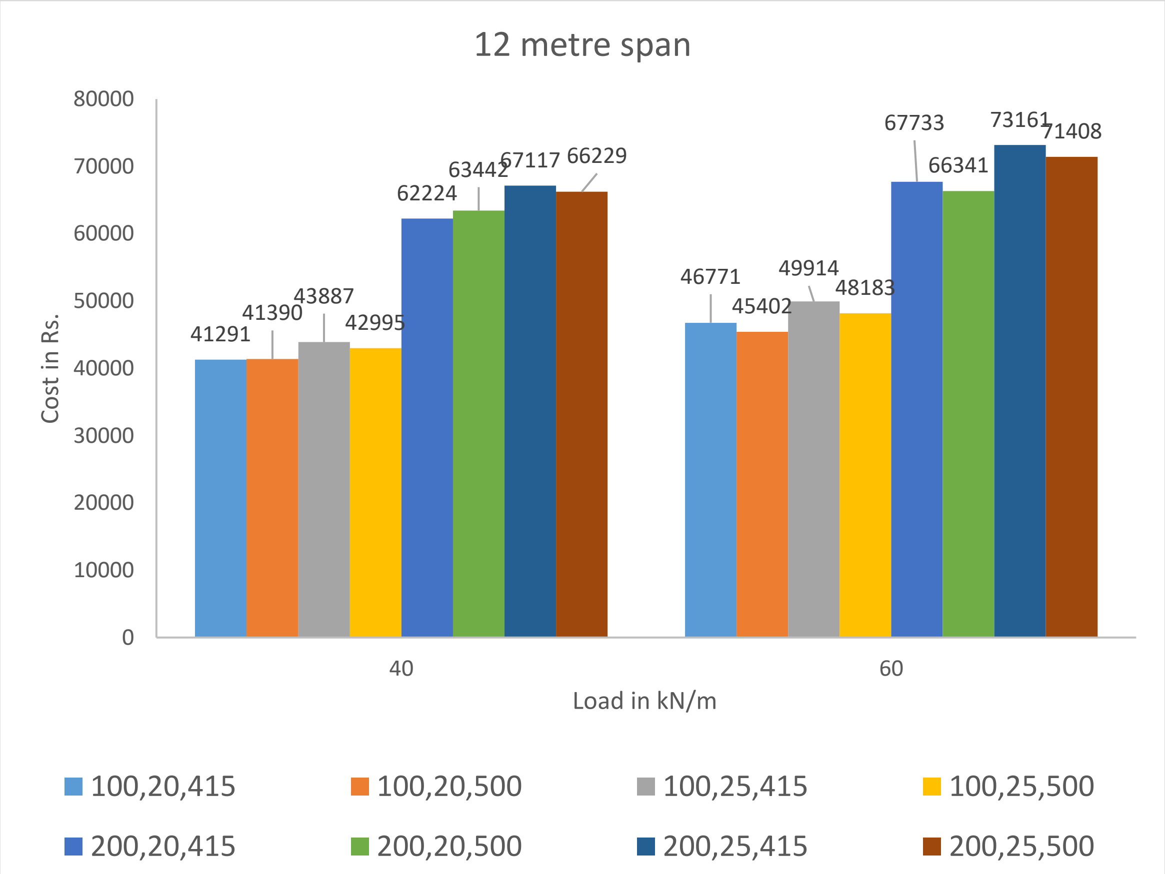

Figure 6: Cost vs. Load graph of Tbeam for 12 metre span

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5. CONCLUSIONS

For 4 and 6 metre span - l/d ratio=5-10, gives the optimum cost for our problem consideration.
For 8, 10 and 12 metre span -l/d ratio =10-16, gives the optimum cost for our problem consideration.
M20 and Fe500 gives us the optimum results for the problem consideration.
It is not always true that higher grade will always results in minimum cost.
Good choice of material is requisite to optimise the cost.

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