Optimal Design of Concrete Element Using Annova And Artificial Neural Network

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***Abstract*-Beam elements are designed and the total cost of each of these has been estimated. The grade of concrete has been varied from M20 to M40 and grade of steel variedfrom Fe 250 to Fe 550. The singly reinforced beams have been designed for various values of live loads and adopting the ratio of b/D from 0.4 to 0.9. In this paper, it is shown that how the decision variables like b, D, Fck, Fy, Asprov, Mu, Vu etc. and the Main Objective of this project has been finalized Minimizing Beam Element Total Cost (BETC). Material and labor and formwork costs are found out. This paper deals with designing a low cost RCC beam in MATLAB. The results from the software and the results from manual design are compared and finally the optimal design of the beams is explained in detail from the various graphs obtained from both the sources.**

***Index Terms*-Decision Variables, Objective function, MATLAB, beams**

1. INTRODUCTION

RCC Beam Designs involves - based upon the Preliminary Sizing and subjected loads, - the calculation Design Forces from Analysis (Mu, Vu etc) (ị). Thereupon evaluation of various decision variables such as formwork cross section sizes – b, D, grade of concrete & reinforcement steel material respectively - Fck, Fy respectively, Area of steel - As & its length, position & arrangement of reinforcement for various steel such – Longitudinal and Transverse Steel are made such that resultant strength & serviceability requirements are satisfied. Optimization means making things the best.

Thus, structural optimization is the subject ofmaking an assemblage of materials sustains loads in the best way. We want to find the structure that performs this task in the best possible way. However, to make any sense out of that objective we need to specify the term "best." The specification that comes to mind may be to make the structure as minimizing total cost.

2. OBJECTIVES

- Development of computer models to automate the design process of reinforced beams according to IS 456 Code.
- Development of TAGUCHI models using MINITAB software
- Development neural network optimizationmodels using MATLAB software.
- To found the factors which influence the totalcost.
- To fond the optimal solution.

3. DESIGN OPTIMIZATION PROBLEM FORMULATION

In this section, the model of the RC beam is described, showing the fixed parameters, the design variables, the design variables' bounds, the design constraints and the objective function. A typical simply supported rectangular RC beam has a span of L m and may be carrying a Moment kN-m. The grades of concrete considered are M20, M25, M30, M35 and M40.

3.1. INDEPENDENT DECISION VARIABLES

b : Discr. Beam width (mm)

(ex-200, 250, 300, 400 ..mm etc)

(bLL< = b < = bUL, i.e b- Lower and Upper Bound Value)D : Discr. Beam Overall Depth (mm)
(ex-300, 450, 600, 750 ..mm etc)
(DLL< = D < = DUL, i.e D- Lower and Upper Bound Value)Fck : Grade of Concrete (N/mm^2).
(ex- Fck 20, 25, 30,35,40.N/mm^2 etc)
Fy : Grade of Reinforcement Steel (N/mm^2).
(ex- Fy 250, 415, 500,550 N/mm^2 etc).

3,2. MATERIAL COST

Cost of M20 concrete = Rs 4394 /m^3 Cost of M25 concrete = Rs 4440 /m^3 Cost of M30 concrete = Rs 4637 /m^{3}Cost of M35concrete = Rs 4933 /m^{3}Cost of M40 concrete = Rs 5327 /m^3

Cost of Fe250 steel = Rs 46 /kg
Cost of Fe415 steel = Rs 52 /kg
Cost of Fe500 steel = Rs 55 /kg
Cost of Fe550 steel = Rs 57 /kg

3.3 R.C MEMBER

Six hundred R.C beams are designed for moments in the range of 100kN-m to 300 kN-m and b/D in the range of 0.4 to 0.9.The grades of concrete considered are M20, M25, M30, M35 and M40.The grades of steel adopted – Fe 250, Fe415,Fe 500 and Fe550 .for example,(only given b/D=0.4)

4.0 COST INFLUENCING FACTORS FOR SINGLY REINFORCED BEAM

Six hundred R.C singly reinforced beams have been designed for bending moment of 100kN- m to 300kN-m with b/D ratio 0.4 to 0.9. The grades of concrete considered are M_{20}, M_{25}, M_{30}, M_{35} and M_{40}.The grades of steel adopted are Fe_{250}, Fe_{415}, Fe_{500} and Fe_{550}.The program have been developed using C language for the design of all the above mentioned structural components and MS -Excel has been made use of it. The estimation of cost of each of the designed structural element has been determined by using Excel sheets.

Parameters		Levels			
		1	2	3	4
A	M	100	150	200	250
B	Fck	20	25	30	35
C	Fy	250	415	500	550
D	b/D	0.4	0.5	0.6	0.7

Table 01 Parameters and their values corresponding to their levels are studied from design for singly reinforced beam

The orthogonal array L_{16} is selected for the design to get the optimum input for obtaining minimum total cost. In this design the major input parameters are Moment, Fck, Fy and b/D are varied for four levels of the values are shown in Table 01. For the input parameters orthogonal array L_{16}as shown on the Table 01 and 02.

S.no	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	1	4	4	4
5	2	1	2	3
6	2	2	1	4
7	2	3	4	1
8	2	4	3	2
9	3	1	3	4
10	3	2	4	3
11	3	3	1	2
12	3	4	2	1
13	4	1	4	2
14	4	2	3	1
15	4	3	2	4
16	4	4	1	3

Table 02 Input data arrangement L16 Orthogonal array for singly reinforced beam

5.0 RESULT AND DISCUSSION

Taguchi technique is used as a time consumption and to give accurate results. The main objective of using taguchi is to identify the optimal operating condition to obtain the minimum cost. For L_{16} (4^4) has 16 trails has been carried out and repeated the trail four times to reduce the uncontrollable external factors that affects the design. The total cost for the trail is shown in the Table 03.

SI.no	Moment kN-m	Fck N/mm^2	Fy N/mm^2	b/D Ratio	Total Cost(Rs)
1	100	20	250	0.4	1195
2	100	25	415	0.5	1098
3	100	30	500	0.6	1198
4	100	35	550	0.7	1265
5	150	20	415	0.6	1592
6	150	25	250	0.7	1958
7	150	30	550	0.4	1178
8	150	35	500	0.5	1337
9	200	20	500	0.7	2038
10	200	25	550	0.6	2167
11	200	30	250	0.5	1517
12	200	35	415	0.4	1165
13	250	20	550	0.5	2898
14	250	25	500	0.4	1488
15	250	30	415	0.7	2130
16	250	35	250	0.6	2574

Table 03 Designed Data for L16 combination for singly reinforced beam

The Minitab software was used to analyze the collected data. In this experiment for obtaining the minimum total cost performance characteristic select shorter the better. The formula to find the signal to noise ratio for larger is better.

$$S=-10 \log 10\{(1/r)\sum^{r} (y)\}$$

Where ,

r is the number of trial for the levels of the noise factors Y_i= values of average total cost

level	Moment kN-m	Fck N/mm^2	Fy N/mm^2	b/D Ratio
1	1189	1931	1811	1257
2	1516	1678	1496	1713
3	1722	1506	1515	1883
4	2273	1585	1877	1848
Delta	1084	425	381	626
Rank	1	3	4	2

Table 04 Response table for singly reinforced beam

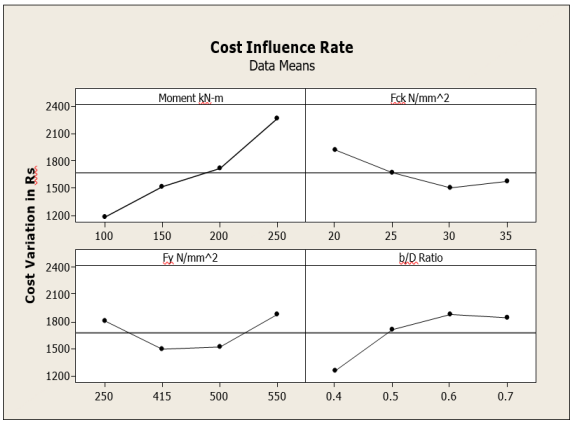

Fig 01 Cost influence factors for singly reinforced beam

ANNOVA is a method used to identify the contribution of each input parameter. From the result of ANNOVA operating moment has the large effect on the cost of element. In the weight level made the confidence level as 92.87%. The moment is the primary significant factor on the cost of element and the percentage of contribution for moment is 52.23%.

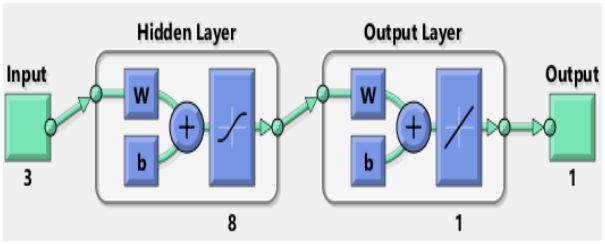

Fig 02 Artificial neural network arrangement for singly reinforced beam

6. CONCLUSIONS

1. Results from Taguchi and Annova technique

- Mainly four factors influence the total cost of singly reinforced beam elements, namely Moment, fck, fy, b/D ratio
- Optimal solution for design of singly reinforced beam using M30 grade of concrete and Fe 500 grade of steel and b/D ratio of 0.4
- In ANNOVA method, it clearly shows that
  - 52% total cost is influenced by moment
  - 21% total cost is influenced by b/D ratio
  - 10% total cost is influenced by fck
  - 8% total cost is influenced by fy.

2. Results from artificial neural network

- The design data chosen for testing purpose using ANN technique in MATLAB. These valves are used to the optimum values
- Using this input parameter the optimized valves of total cost is obtained.
- Trained experimental minimum error is 0.000001254
- Tested experimental minimum error is 0.000001212
- By comparing manual valve and ANN 99% of accuracy was obtained.

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