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Least Cost Design of Simply Supported Beams using Genetically Optimized Artificial Neural Network

Karthiga Shenbagamn N*

Bannari Amman Institute of Technology, Sathyamangalam, Erode District, TamilNadu, India

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 varied from 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.
Key Words : Decision Variables, Objective function, MATLAB, cost, Singly Reinforced beams, Minimization beam.

1.Introduction

RCC Beam Designs involves - based upon the Preliminary Sizing and subjected loads, - the calculation Design Forces from Analysis (Mu, Vu etc) (i). 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 of making 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

The following objectives are defined to achieve the research goal:

- 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 optimization models using MATLAB software.
- To found the factors which influence the total cost.

- To fond the optimal solution.

3. SCOPE

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. bending moment about minor axis in the range of 50kN-m to 350kN-m.The grades of concrete considered are M20, M25, M30, M35 and M40.The grades of steel adopted – Fe 250, Fe415 and Fe 500.Computer programs 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 estimated costs of each of the designed structural elements have been determined. Factors which influenced the cost have been determined by using Minitab software. A set of neural network have been made use of to predict the cost of elements. Results of this neural network have been compared with the results obtained by hand calculation.

4. **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.The grades of steel adopted – Fe 250, Fe415, Fe 500 and Fe550. It is intended to optimize the design of the beam according to the provisions of the IS-456 Code.

4.2.1 The Fixed Parameters

The fixed parameters for this RC simple beam model are taken as the span of the beam, the cost/m3 of concrete, the cost/Kg of steel, the modulus of elasticity of concrete, the compressive strength of concrete, the yield strength of reinforcement and the value of the Moments.

4.2.2 Design Variables

The design variables which are considered in this RC beam model are listed below:

Independent Decision Variables

b : Discr. Beam width (mm)
(ex-200, 250, 300, 400 ..mmetc)
(bLL< = b < = bUL, i.e b- Lower and Upper Bound Value)
D :Discr. Beam Overall Depth (mm)
(ex-300, 450, 600, 750 ..mmetc)
(DLL< = D < = DUL, i.e D- Lower and Upper Bound Value)
Fck : Grade of Concrete (N/mm2).
(ex- Fck 20, 25, 30,35,40.N/mm2 etc)
Fy : Grade of Reinforcement Steel (N/mm2).
(ex- Fy 250, 415, 500,550 N/mm2 etc).

Independent Preassigned Design Decision Parameters

Lclr :Clear Length of the beam between support
Mu: Fact.Bending Moment (KN.M).
Vu : Factored Shear force (KN)
pAsmax : 4% or Even lesser User Defined (Max. Percentage Steel)

Dependent Preassigned Design Decision Parameters

CC, CS, CF : Unitary Rate of Concrete, Formwork, Reinforcement Steel respectively – with Material supply, Labour, Fixing and placement all inclusive.
Xumax/deff : Neutral Axis ratio as per steel grade.
Q : Limiting Moment of resistance Factor.=0.36* (Xumax /deff)*(1-0.42*Xumax/deff)*Fck
pAsmin : 0.85/ Fy *100 (Min. Percentage Steel)

Concrete Cost

Cost of M20 concrete = Rs3892 /m^3
Cost of M25 concrete = Rs4015 /m^3
Cost of M30 concrete = Rs 4279 /m^3
Cost of M35concrete = Rs 4439 /m^3
Cost of M40 concrete = Rs4706 /m^3

Steel Cost

Cost of Fe250 steel = Rs46 /kg
Cost of Fe415 steel = Rs48 /kg
Cost of Fe500 steel = Rs 55 /kg
Cost of Fe550 steel = Rs 57 /kg

Formwork Cost

Cost of Formwork = Rs 350 /m^2

Dependent Design Decision Variables

Asmin :pAstmin * b *deff /100 (Min. Area of Steel)
Asmax :pAsmax * b *D /100 (Max. Area of Steel)
Mulim : Q * b * $deff^2$ (Limiting Moment)

Singly reinforced design :

MuMax<= Mulim , Then Tension Steel Area reqd
Astreqd = 0.5 *Fck/Fy*[1 – Sqrt (1-4.6*MuMax / (Fck*b*deff2))] *b*deff

Shear Design:

v = Vu / b * deff (Nominal shear Stress)
Pt=100Ast/ b*d
c = Depending upon Astprov (Area of Steel Tension provided) and Grade of Concrete Fck.
C > v (hence safe)
Vus = Vu –(c * b *deff)-Transverse Steel Shear resistance Required.
Vus_pr = 0.87 *Fy * Asv_pr *deff / Sv_pr

4.2.3design Constraints

A)Bending Strength Related Constraints :

1) MuMax< = MOR_pr

B) Steel Constraints :

2) Astreqd< = Astprov
3) Astprov< = Asmax
4) Asmin< = Astprov
5) deff< = deff_pr

C) Side Face Steel Constraints :

7) AS_SF_reqd< = AS_SF_prov
8) SFRdistprov< = SFRdistmax

D) Upper and Lower Bound Constr. on Beam Sizes:

9) b< = bUL

10) bLL< = b
11) D < = DUL
12) DLL < = D

4.2.4 Objective Function

The chief task of the optimization process is to select the values of variables in a way that satisfies the provisions of the code regarding safety and serviceability within the least cost possible, the function below defines the total cost of the RC simple beam model in terms of the cost of the concrete and reinforcement and form work used.

It can be stated as Total Beam Element Cost (BE_TC)

i.e. Total of all cost components (Concrete Reinforcement Steel and Formwork) :

BE_TC = BE_CC + BE_FC + BE_RC

Concrete Cost

BE_CC : BE_CVOL * CC,

CVOL = b * D * Lclr (Concrete Volume)

Formwork Cost

BE_FC : BE_FA* CF

BE_FA = (Formwork Area)

(Formwork Area) =((Leff*b)+(2*b*D)+(2*Leff*D))* CF

Reinforcement Cost

BE_RC :BE_Rwt * CS

BE_Rwt :LRwt + Tr.Rwt (Reinf Weight),

where LRwt and Tr.Rwt Longitudinal and Transverse Reinf Steel Weight.

LRwt :TLRwt + BLRwt + SFLRwt,

Where TLRwt, BLRwt, SFLRwt are Top, Bottom and Side Face Long. Reinf.Steel wt. respectively.

BE_TC =[(b*D*L)-{(Π/4*d1*d1*Ntr*L)+(Π/4*d2*d2*Ncr*L)+(Π/4*d3*d3*(L/Sv)*Lst)}Cc]+[{(L*b)+(2*b*D)+(2*L*D)}*Cf]+[{(Π/4*d1*d1*Ntr*L*7850*10^-6)+(Π/4*d2*d2*Ncr*L*7850*10^-6)+(Π/4*d3*d3*(L/Sv)*Lst*7850*10^6)}*Cr

4. 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)

4.1 Tabulation

SI.NO	Fck N/mm^2	Fy N/mm^2	Moment kN-m	Depth mm	Breath mm	Ast mm^2	Asc mm^2	cost for concrete	cost for steel	Cost for Form work	Total cost
1	20	250	100	438	175	1350	202	330	648	95	1073
2	25	250	100	406	163	1454	218	286	670	86	1042
3	30	250	100	382	153	1545	232	263	692	80	1035
4	35	250	100	363	145	1627	244	251	713	76	1040
5	40	250	100	347	139	1701	255	247	734	72	1052
6	20	415	100	449	180	771	116	350	413	98	862
7	25	415	100	417	167	831	125	304	424	89	818
8	30	415	100	392	157	883	132	281	436	83	799
9	35	415	100	373	149	929	139	269	448	78	794
10	40	415	100	356	143	972	146	265	459	74	798
11	20	500	100	455	182	625	94	360	388	99	848
12	25	500	100	422	169	673	101	313	399	91	802
13	30	500	100	397	159	715	107	289	410	84	783
14	35	500	100	377	151	753	113	277	421	79	777
15	40	500	100	361	144	787	118	273	432	73	778
16	20	250	150	501	200	1769	265	432	837	112	1382
17	25	250	150	465	186	1905	286	375	865	102	1342
18	30	250	150	438	175	2025	304	345	893	95	1332
19	35	250	150	416	166	2131	320	329	920	89	1339
20	40	250	150	398	159	2228	334	323	947	84	1355
21	20	415	150	514	206	1011	152	459	535	116	1109
22	25	415	150	477	191	1089	163	399	548	105	1052
23	30	415	150	449	180	1157	174	368	563	98	1028
24	35	415	150	427	171	1218	183	352	578	92	1021
25	40	415	150	408	163	1273	191	347	592	87	1026
26	20	500	150	520	208	819	123	472	499	117	1088
27	25	500	150	483	193	882	132	410	512	107	1029
28	30	500	150	455	182	937	141	378	526	99	1003
29	35	500	150	432	173	986	148	362	540	93	995
30	40	500	150	413	165	1031	155	357	470	88	916
31	20	250	200	552	221	2143	321	524	848	126	1498
32	25	250	200	512	205	2308	346	454	869	115	1438
33	30	250	200	482	193	2453	368	418	891	107	1416
34	35	250	200	458	183	2582	387	399	915	100	1413
35	40	250	200	438	175	2699	405	392	991	95	1477
36	20	415	200	566	226	1224	184	556	550	130	1237
37	25	415	200	525	210	1319	198	483	559	119	1161
38	30	415	200	494	198	1402	210	445	571	110	1126
39	35	415	200	469	188	1475	221	426	583	103	1112
40	40	415	200	449	180	1543	231	420	605	98	1122
41	20	500	200	573	229	992	149	572	523	133	1228
42	25	500	200	532	213	1068	160	497	533	121	1150
43	30	500	200	500	200	1135	170	458	544	112	1115
44	35	500	200	475	190	1195	179	439	557	105	1101
45	40	500	200	455	182	1249	187	433	569	99	1101
46	20	250	250	594	238	2486	373	608	995	139	1742
47	25	250	250	552	221	2678	402	527	1020	126	1673
48	30	250	250	519	208	2846	427	484	1047	117	1649

49	35	250	250	493	197	2996	449	463	1075	110	1647
50	40	250	250	472	189	3132	470	455	1102	104	1661
51	20	415	250	609	244	1421	213	645	641	143	1430
52	25	415	250	566	226	1530	230	561	651	130	1342
53	30	415	250	532	213	1626	244	517	665	121	1302
54	35	415	250	506	202	1712	257	495	679	113	1287
55	40	415	250	484	193	1790	268	487	693	107	1288
56	20	500	250	617	247	1151	173	663	598	146	1407
57	25	500	250	573	229	1240	186	576	608	133	1317
58	30	500	250	539	216	1317	198	532	621	123	1275
59	35	500	250	512	205	1387	208	509	634	115	1259
60	40	500	250	490	196	1450	217	502	648	109	1259
61	20	250	300	631	253	2808	421	686	1124	150	1961
62	25	250	300	586	234	3024	454	595	1152	136	1883
63	30	250	300	552	221	3214	482	547	1183	126	1856
64	35	250	300	524	210	3383	507	522	1214	118	1855
65	40	250	300	501	200	3537	531	513	1245	112	1870
66	20	415	300	648	259	1604	241	729	724	155	1608
67	25	415	300	601	240	1728	259	633	736	141	1509
68	30	415	300	566	226	1836	275	584	750	130	1465
69	35	415	300	537	215	1933	290	559	766	122	1447
70	40	415	300	514	206	2021	303	550	783	116	1449
71	20	500	300	656	262	1299	195	749	675	158	1582
72	25	500	300	609	243	1400	210	651	686	143	1481
73	30	500	300	573	229	1488	223	569	701	133	1402
74	35	500	300	544	218	1566	235	518	716	124	1358
75	40	500	300	520	208	1637	246	494	1464	117	2075
76	20	550	100	458	183	560	84	366	581	100	1046
77	25	550	100	425	170	604	91	318	607	91	1016
78	30	550	100	400	160	641	96	293	631	85	1010
79	35	550	100	380	152	675	101	281	655	80	1016
80	40	550	100	363	145	706	106	277	469	76	822
81	20	550	150	524	210	734	110	479	531	118	1129
82	25	550	150	487	195	791	119	416	548	108	1072
83	30	550	150	458	183	840	126	384	565	100	1049
84	35	550	150	435	174	885	133	368	581	94	1044
85	40	550	150	416	166	925	139	363	430	89	882
86	20	550	200	577	231	889	133	581	477	134	1191
87	25	550	200	536	214	958	144	505	484	122	1111
88	30	550	200	504	202	1018	153	466	494	113	1072
89	35	550	200	479	191	1072	161	446	504	106	1056
90	40	550	200	458	183	1121	168	440	514	100	1054
91	20	550	250	621	249	1032	155	674	554	147	1375
92	25	550	250	577	231	1112	167	585	562	134	1281
93	30	550	250	543	217	1181	177	540	573	124	1237
94	35	550	250	516	206	1244	187	518	585	116	1218
95	40	550	250	493	197	1300	195	510	597	110	1217
96	20	550	300	660	264	1165	175	761	625	159	1545
97	25	550	300	613	245	1255	188	661	635	145	1440
98	30	550	300	577	231	1334	200	610	647	134	1391
99	35	550	300	548	219	1404	211	585	660	125	1370
100	40	550	300	524	210	1468	220	576	674	118	1369

5.2 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.

Table5.3. Parameters and their values corresponding to their levels are studied from design for singly reinforced beam

Parameters		**Levels**			
		1	**2**	**3**	**4**
A	Moment	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

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 5.3. For the input parameters orthogonal array L_{16}as shown on the table 5.3 and 5.4

Table 5.4 Input data arrangement L_{16} Orthogonal array for singly reinforced beam

SI.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 5.5 L_{16} Orthogonal array for singly reinforced beam

SI.no	**Moment kN-m**	**Fck N/mm^2**	**Fy N/mm^2**	**b/D Ratio**
1	100	20	250	0.4
2	100	25	415	0.5
3	100	30	500	0.6
4	100	35	550	0.7
5	150	20	415	0.6
6	150	25	250	0.7
7	150	30	550	0.4

8	150	35	500	0.5
9	200	20	500	0.7
10	200	25	550	0.6
11	200	30	250	0.5
12	200	35	415	0.4
13	250	20	550	0.5
14	250	25	500	0.4
15	250	30	415	0.7
16	250	35	250	0.6

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 5.6.

Table 5.6 Designed Data for L_{16} combination for singly reinforced beam

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

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.

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

Where ,

r is the number of trial for the levels of the noise factors

Y_i= values of average total cost

The factors are classified into control factors and noise factors. The DOE for obtaining graph for the obtained results. In the response table for the ranking for each input parameters are obtained as follows.

Table 5.7 Response Table for singly reinforced beam

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

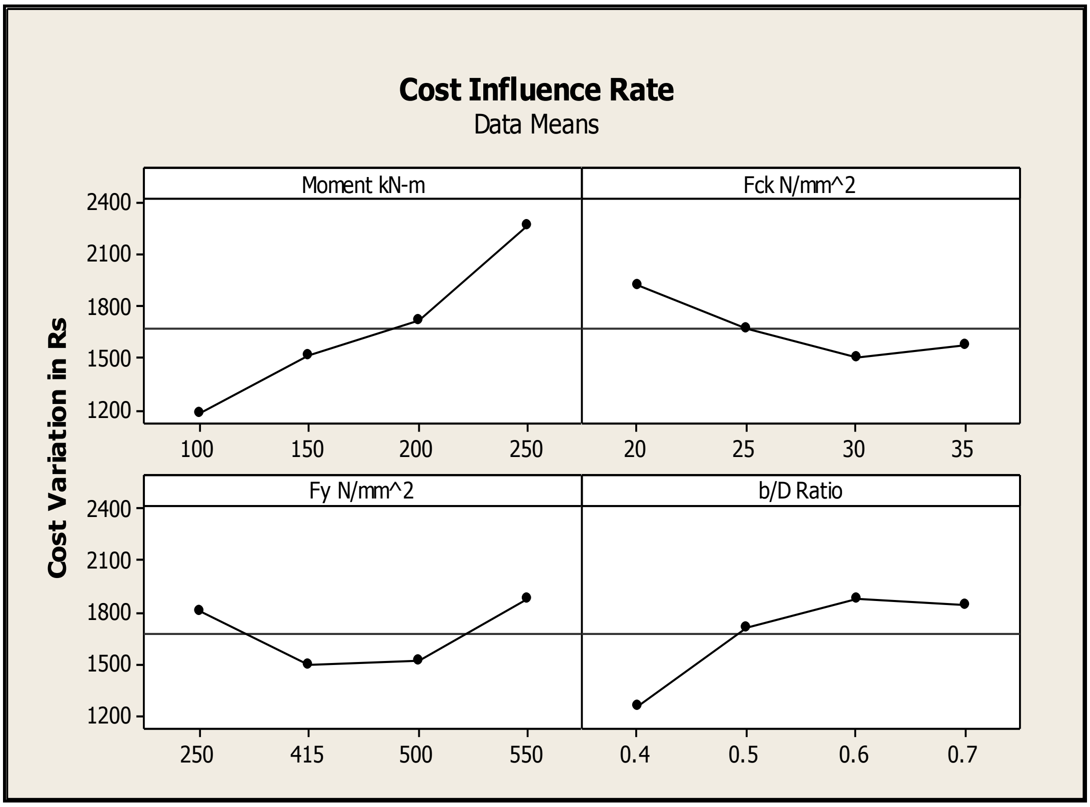

Fig 5.1 Cost influence factors for singly reinforced beam

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%.

Table 5.8 Result of ANNOVA for L_{16} design for singly reinforced beam

FACTOR	DOF	Sum of square	Variance	Contribution (%)
A	2	2482357	1241179	52.23847911
B	2	408464.8	204232.4	8.856545674
C	2	467086.3	233543.1	10.1276076
D	2	998204.3	499102.1	21.64358499
ERR	7	255897.3	36556.75	7.13378262
TOTAL	15			92.873

6.2 Singly Reinforced Beam

Input Data For Neural Network

Table 6.1 Training data for singly reinforced beam

SI.NO	Fck N/mm^2	Fy N/mm^2	b/D Ratio	Moment kN-m	Total cost Rs
1	20	250	0.4	100	1195
2	25	250	0.4	100	1154
3	30	250	0.4	100	1139
4	35	250	0.4	100	1138
5	40	250	0.4	100	1145
6	20	415	0.4	100	988
7	25	415	0.4	100	933
8	30	415	0.4	100	906
9	35	415	0.4	100	895
10	40	415	0.4	100	893
11	20	500	0.4	100	976
12	25	500	0.4	100	920
13	30	500	0.4	100	892
14	35	500	0.4	100	879
15	40	500	0.4	100	872
16	20	250	0.4	150	1526
17	25	250	0.4	150	1474
18	30	250	0.4	150	1455
19	35	250	0.4	150	1454
20	40	250	0.4	150	1464
21	20	415	0.4	150	1259
22	25	415	0.4	150	1188
23	30	415	0.4	150	1155
24	35	415	0.4	150	1140
25	40	415	0.4	150	1138
26	20	500	0.4	150	1240
27	25	500	0.4	150	1167
28	30	500	0.4	150	1132
29	35	500	0.4	150	1116
30	40	500	0.4	150	1030
31	20	250	0.5	200	1988
32	25	250	0.5	200	2002
33	30	250	0.5	200	1926
34	35	250	0.5	200	1981
35	40	250	0.5	200	2028
36	20	415	0.5	200	1740
37	25	415	0.5	200	1593
38	30	415	0.5	200	1518
39	35	415	0.5	200	1643
40	40	415	0.5	200	1495
41	20	500	0.5	200	1703
42	25	500	0.5	200	1575
43	30	500	0.5	200	1635
44	35	500	0.5	200	1588
45	40	500	0.5	200	1560
46	20	250	0.5	250	2311
47	25	250	0.5	250	2290
48	30	250	0.5	250	2183
49	35	250	0.5	250	2290

50	40	250	0.5	250	2255
51	20	415	0.5	250	1893
52	25	415	0.5	250	1921
53	30	415	0.5	250	1814
54	35	415	0.5	250	1760
55	40	415	0.5	250	1728
56	20	500	0.5	250	1995
57	25	500	0.5	250	1848
58	30	500	0.5	250	1760
59	35	500	0.5	250	1686
60	40	500	0.5	250	1807
61	20	250	0.6	100	1511
62	25	250	0.6	100	1486
63	30	250	0.6	100	1496
64	35	250	0.6	100	1458
65	40	250	0.6	100	1500
66	20	415	0.6	100	1338
67	25	415	0.6	100	1196
68	30	415	0.6	100	1210
69	35	415	0.6	100	1174
70	40	415	0.6	100	1137
71	20	500	0.6	100	1296
72	25	500	0.6	100	1170
73	30	500	0.6	100	1198
74	35	500	0.6	100	1162
75	40	500	0.6	100	1140
76	20	250	0.6	150	1952
77	25	250	0.6	150	1832
78	30	250	0.6	150	1899
79	35	250	0.6	150	1850
80	40	250	0.6	150	1920
81	20	415	0.6	150	1593
82	25	415	0.6	150	1475
83	30	415	0.6	150	1513
84	35	415	0.6	150	1466
85	40	415	0.6	150	1422
86	20	500	0.6	150	1698
87	25	500	0.6	150	1578
88	30	500	0.6	150	1505
89	35	500	0.6	150	1458
90	40	500	0.6	150	1426
91	20	250	0.7	200	2112
92	25	250	0.7	200	2088
93	30	250	0.7	200	2054
94	35	250	0.7	200	2112
95	40	250	0.7	200	2172
96	20	415	0.7	200	1683
97	25	415	0.7	200	1710
98	30	415	0.7	200	1639
99	35	415	0.7	200	1596
100	40	415	0.7	200	1569
101	20	500	0.7	200	1802
102	25	500	0.7	200	1675
103	30	500	0.7	200	1583
104	35	500	0.7	200	1589
105	40	500	0.7	200	1722

106	20	250	0.7	200	2584
107	25	250	0.7	200	2417
108	30	250	0.7	200	2436
109	35	250	0.7	200	2384
110	40	250	0.7	200	2374
111	20	415	0.7	200	2008
112	25	415	0.7	200	1864
113	30	415	0.7	200	1913
114	35	415	0.7	200	1843
115	40	415	0.7	200	1794
116	20	500	0.7	200	1935
117	25	500	0.7	200	1943
118	30	500	0.7	200	1908
119	35	500	0.7	200	1839
120	40	500	0.7	200	1812
121	20	250	0.8	100	1490
122	25	250	0.8	100	1455
123	30	250	0.8	100	1390
124	35	250	0.8	100	1425
125	40	250	0.8	100	1406
126	20	415	0.8	100	1180
127	25	415	0.8	100	1166
128	30	415	0.8	100	1102
129	35	415	0.8	100	1072
130	40	415	0.8	100	1126
131	20	500	0.8	100	1170
132	25	500	0.8	100	1168
133	30	500	0.8	100	1118
134	35	500	0.8	100	1073
135	40	500	0.8	100	1057
136	20	250	0.8	150	1919
137	25	250	0.8	150	1829
138	30	250	0.8	150	1866
139	35	250	0.8	150	1809
140	40	250	0.8	150	1887
141	20	415	0.8	150	1582
142	25	415	0.8	150	1453
143	30	415	0.8	150	1390
144	35	415	0.8	150	1352
145	40	415	0.8	150	1481
146	20	500	0.8	150	1557
147	25	500	0.8	150	1427
148	30	500	0.8	150	1364
149	35	500	0.8	150	1326
150	40	500	0.8	150	1287

Results and Conclusion:

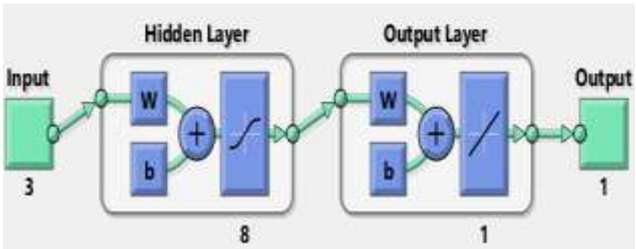

Fig 6.4 Artificial neural network arrangement for singly reinforced beam

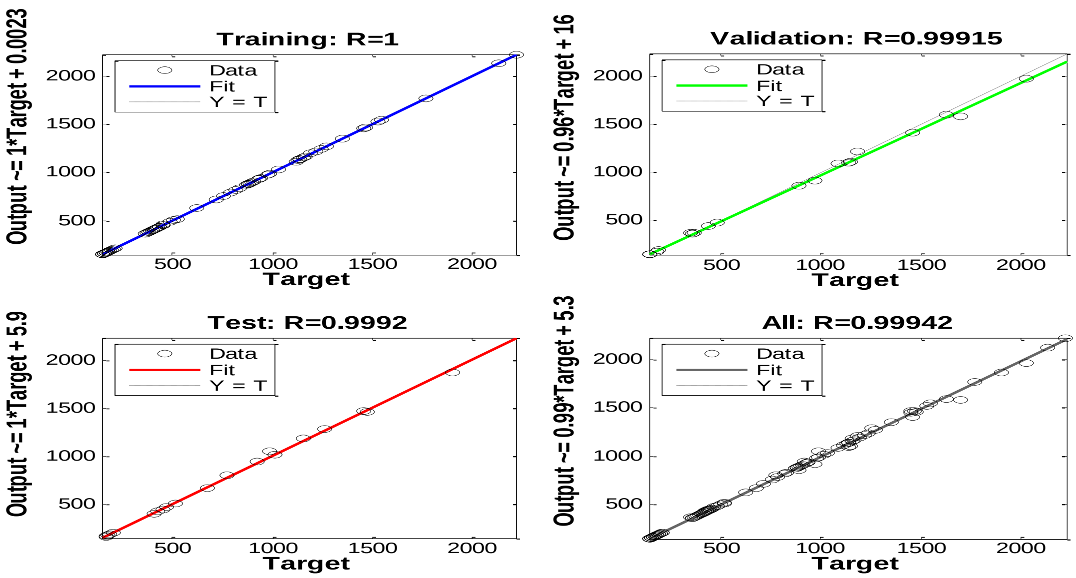

Fig 6.5 Graph showing accuracy of result for singly reinforced beam

Table6.2 Testing Data of ANN for singly reinforced beam

SI. no	Fck N/mm^2	Fy N/mm^2	b/D Ratio	Moment kN-m	Neural network result Total cost Rs	Obtained result Total costRs	percentage
1	20	250	0.4	300	2094	2155	0.418183
2	25	250	0.4	300	1998	2060	0.530152
3	30	250	0.4	300	2073	2020	0.279355
4	35	250	0.4	300	1953	2008	0.595195
5	40	250	0.4	300	2067	2015	0.793499
6	20	415	0.4	300	1754	1809	0.812473
7	40	415	0.5	100	2223	2189	0.450567
8	20	500	0.5	100	3496	3562	0.377053
9	25	500	0.5	100	3142	3070	0.457049
10	30	500	0.5	100	2648	2719	0.726416
11	35	500	0.5	100	2394	2453	0.578064
12	40	500	0.5	100	2195	2244	0.634968
13	20	500	0.6	300	2356	2311	0.452037
14	25	500	0.6	300	2286	2332	0.249636
15	30	500	0.6	300	2186	2224	0.70809
16	35	500	0.6	300	2193	2155	0.610928
17	40	500	0.6	300	2069	2114	0.220687

Table 6.2 shows 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 0.00001254 and tested experimental minimum error is 0.000012123. by comparing experimental valve and ANN 99% of accuracy was obtained.

Result and Conclusions

Singly Reinforced Beam

7.1.1Results from Taguchi and Annova technique

- Mainly four factors influence the total cost of singly reinforced beam elements, namely Moment, fck, fy, b/D ratio.

- We got 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.

7.1.2 Results from artificial neural network

- The table 6.2 shows 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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