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Optimal design of RC Columns subjected Touniaxial bending

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Abstract : Optimization is a technique adopted to identify the best solution, a set of many feasible solutions without having to evaluate all possible solutions. The conventional design of R.C.columns subjected to a load and uniaxial moment does not give a unique solution. The solution depends on the choice of the designer in selecting the design parameters like breadth of columns, depth of columns, and percentage of steel and grade of concrete. Eight hundred and sixty four columns were designed to demonstrate that optimal solution exists and the optimal cost is much lower than the cost of the columns designed by conventional method [1]. It is found that M40 grade of concrete is the best grade to be adopted for columns with load and uniaxial moment.

1.0 Introduction:

Optimization is finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones. The theory of optimization, as stated by Ravindran et al is a system of numerical methods and mathematical results for finding and identifying the best candidate from a collection of alternatives without having to explicitly enumerate and evaluate all possible alternatives[3]. This means that optimization might be considered as a time-saving task enabling the expenditure of less effort for achieving a superior outcome.

Design of reinforced concrete columns subjected to load and moments involves solution by trial and error method. The dimensions are assumed and the sections are to be checked for adequacy as per the codal provisions. The designers have many options in selecting the dimensions and hence all designs will not give the same cost. Only one design will give least cost. During the present work an attempt has been made to design many columns to demonstrate that there is an optimal solution and the cost of the optimal design is much lower than the cost of other columns.

2.0 Literature Review:

Bari.S and Mamun.A.A developed a cost optimization technique for the design of columns. They reported that using 5000 psi concrete instead of 3000 psi concrete saves 20-50 percent of total cost in general. For same axial load and moment resisting capacity, a circular column was found to be more costly than a square column. Also, the cost differences between circular and square columns increased with the increase in gross area of concrete.

Sonia ChutaniandJagir Singh developed an economic design for reinforced concrete columns. They repeated that optimum designs were achieved at minimum percentage of steel and minimum width of column specified by the designer. Particle swarm optimization which is a population based stochastic optimization method was adopted by them.

Poonam Gare and Angalekar.S.S developed a design procedure to get optimal design of singly reinforced concrete beams and short axially loaded column. They used Generalized Reduced Gradient (GRG) method.They utilized the excel solver toolbox to get the results. They reported that the reduction in the weight of singly reinforced beams is around 37% when generalized reduced gradient technique was adopted.Incaseof axially loaded short columns they reported that the reduction in cost was around 30%.

Rafiq.M.Y used Genetic Algorithm to optimize the area of reinforcement steel required for reinforced concrete columns with uni-axial and bi-axial bending [4]. Column design, bending capacity checks and final bar detailing were included in the optimization code.

Sudarsana Rao.H and Ramesh Babu developed a method for the optimal design of columns using genetic algorithm based neural networks[5]. They demonstrated the applicability of artificial neural networks (ANN) and genetic algorithms (GA) for the design of short columns under biaxial bending.[6] A hybrid neural network model that combines the features of feed forward neural networks and genetic algorithms was developed for the design of short columns. It was concluded that GA based neural network model provided optimal solution automatically[8].

3.0 Methodology:

An excel spread sheet was developed to design columns subjected to uniaxial bending. Two loads and four moments were considered. Three breadths and nine depths were considered in order to study the effect of grade of concrete on cost of columns. Columns were designed with four grades of concrete. The details of the columns designed are shown in Fig 1 (Please refer annexure 1).Eight hundred and sixty four columns were designed.

4.0 Results and discussion:

The columns were designed as per the charts given in"Design Aids for Reinforced Concrete to IS456-1978"[7].The details of the columns designed are shown in Fig 1. It was found that few columns designed have reinforcement percentage outside the range specified in IS:456;2007.Some columns have the percentage of steel less than 0.8% and few others had reinforcement percentage above 6%.These designs were eliminated and the results were analyzed. The details of the columns designed with M20 concrete for a load of 1200kN and a moment of 90kN-m are given in Table 1.(please refer annexure 2)From the Table 1, it can be seen that the designers can design many columns in the feasible range. For the given load and moment, it can be seen that the column of size 230X600mm having 0.8% of reinforcement has the cost of only Rs1971.The highest cost is obtained for the column of size 300X300mm having a reinforcement percentage of 5.2.

The difference between the highest and lowest cost of columns is almost 53%.Hence the columns should not be arbiterily designed but will have to be optimally designed.

Table:1 Details of columns with a load of 1200kN and a moment of 90kN-m designed with M20 grade

S.no	**Breadth (mm)**	**Depth (mm)**	$\frac{p_u}{f_{ck}bd}$	$\frac{m_u}{f_{ck}bd^2}$	$\frac{d'}{D}$	$\frac{P}{f_{ck}}$	**Percentage of steel**	**Area of Steel (mm^2)**	**Cost**
1	300	300	0.67	0.17	0.18	0.26	5.2	4680	Rs3023
2	230	350	0.75	0.16	0.15	0.22	4.4	3542	Rs2467
3	350	350	0.49	0.10	0.15	0.1	2	2450	Rs2345
4	230	400	0.65	0.12	0.13	0.16	3.2	2944	Rs2321
5	350	400	0.43	0.08	0.13	0.06	1.2	1680	Rs2159
6	300	450	0.44	0.07	0.12	0.06	1.2	1620	Rs2105
7	230	550	0.47	0.06	0.10	0.06	1.2	1518	Rs2039
8	230	600	0.43	0.05	0.09	0.04	0.8	1104	Rs1971
9	300	500	0.40	0.06	0.11	0.04	0.8	1200	Rs2055
10	230	500	0.52	0.08	0.11	0.08	1.6	1840	Rs2068
11	230	450	0.58	0.10	0.12	0.12	2.4	2484	Rs2234

12	300	400	0.50	0.09	0.13	0.1	2	2400	Rs2309
13	300	350	0.57	0.12	0.15	0.14	2.8	2940	Rs2411
14	350	300	0.57	0.14	0.18	0.18	3.6	3780	Rs2768

4.1 Effect of grade of concrete on the optimal cost of columns:

In order to determine the effect of grade of concrete on the optimal cost of columns, columns were designed with M20, M30, M40, and M50 grades of concrete [2].Table 2 gives details of optimal design of columns designed with different grades of concrete.

Table 2.Details of Columns Designed with Different Grades of Concrete.

Grade		M20	M30	M40	M50	% saving in cost
Load(kN)	1200	Rs1970	RS1725	Rs1516	Rs1648	30
Moment(kN-m)	90					
Load(kN)	1200	Rs2038	Rs1924	Rs1516	Rs1648	34
Moment(kN-m)	100					
Load(kN)	1200	Rs2054	Rs1895	Rs1671	Rs1987	23
Moment(kN-m)	110					
Load(kN)	1200	Rs2054	Rs2041	Rs1681	Rs1855	22
Moment(kN-m)	120					
Load(kN)	1500	Rs2205	Rs2077	Rs1681	Rs1855	31
Moment(kN-m)	90					
Load(kN)	1500	Rs2324	Rs2041	Rs1681	Rs1855	38
Moment(kN-m)	100					
Load(kN)	1500	Rs2324	Rs2041	Rs1846	Rs1855	26
Moment(kN-m)	110					
Load(kN)	1500	Rs2413	Rs2226	Rs1681	Rs2058	44
Moment(kN-m)	120					

Figure 2 shows the variation in the cost of R.C.Columns carrying a load of 1200kN and a moment of 90kN-m.

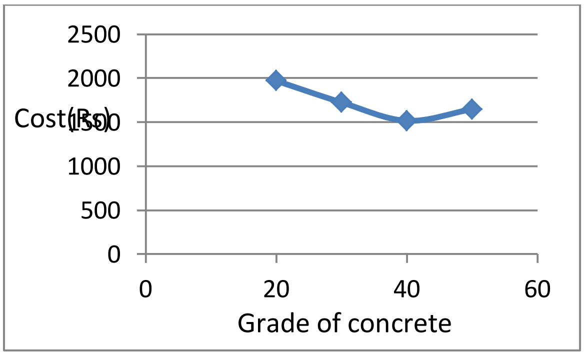

Figure 2: Columns with a Load of 1200kN and a Moment of 90kN-m

From Figure 2, it can be seen that the cost of columns with M40 grade of concrete is the least. The savings in the cost of column made with M20 concrete is 30%.

Figure 3 shows the variation in the cost of R.C.Columns carrying a load of 1200kN and a moment of 100kN-m.

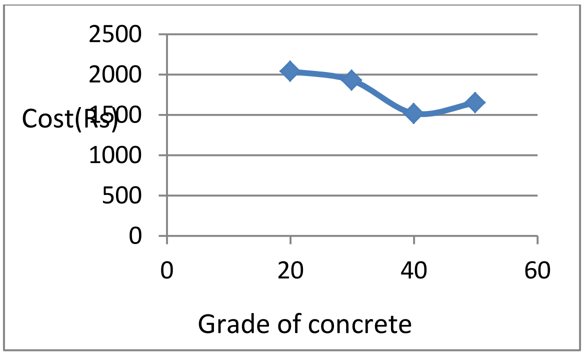

Figure 3:Columns with a Load of 1200kN and a Moment of 100kN-m

From Figure 3, it can be seen that the cost of columns with M40 grade of concrete is the least. The savings in the cost of column made with M20 concrete is 34%.

Figure 4 shows the variation in the cost of R.C.Columns carrying a load of 1200kN and a moment of 110kN-m.

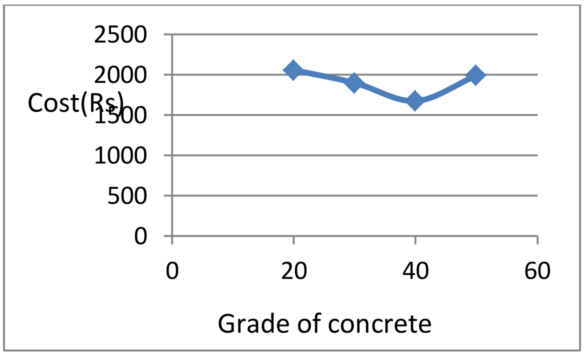

Figure 4: Columns with a Load of 1200kN and a Moment of 110kN-m

From Figure 4, it can be seen that the cost of columns with M40 grade of concrete is the least. The savings in the cost of column made with M20 concrete is 23%.

Figure 5 shows the variation in the cost of R.C.Columns carrying a load of 1500kN and a moment of 90kN-m.

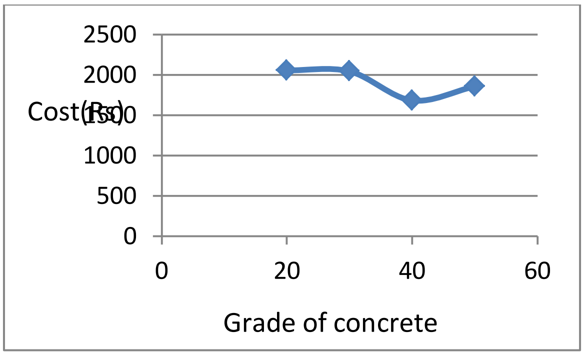

Figure 5:Columns with a Load of 1200kN and a Moment of 120kN-m

From Figure 5, it can be seen that the cost of columns with M40 grade of concrete is the least. The savings in the cost of column made with M20 concrete is 31%.

Figure 6 shows the variation in the cost of R.C.Columns carrying a load of 1500kN and a moment of 100kN-m.

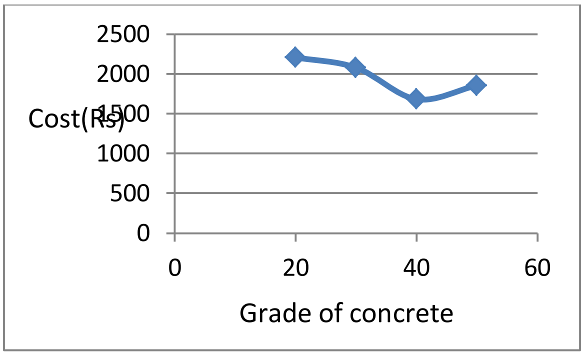

Figure 6:Columns with a Load of 1500kN and Moment of 100kN-m

From Figure 6, it can be seen that the cost of columns with M40 grade of concrete is the least.The savings in the cost of column made with M20 concrete is 38%.

Figure 7 shows the variation in the cost of R.C.Columns carrying a load of 1500kN and a moment of 110kN-m.

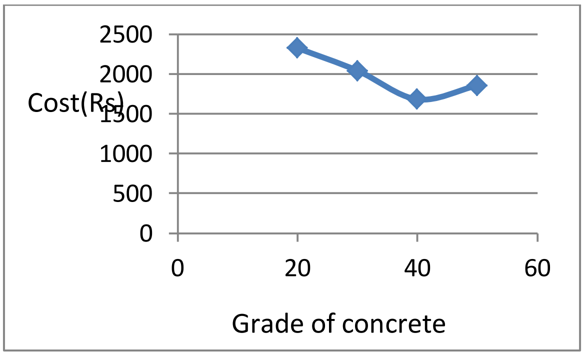

Figure 7:Columns with a load of 1500kN and moment of 110kN-m

From Figure7, it can be seen that the cost of columns with M40 grade of concrete is the least.The savings in the cost of column made with M20 concrete is 26%.

Figure 8 shows the variation in the cost of R.C.Columns carrying a load of 1500kN and a moment of 110kN-m.

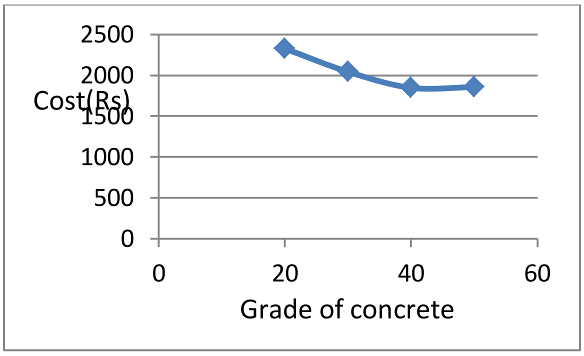

Figure 8:Columns with a Load of 1500kN and a Moment of 110kN-m

From Figure 8, it can be seen that the cost of columns with M40 grade of concrete is the least.The savings in the cost of column made with M20 concrete is 26%.

Figure 9shows the variation in the cost of R.C.Columns carrying a load of 1500kN and a moment of 120kN-m.

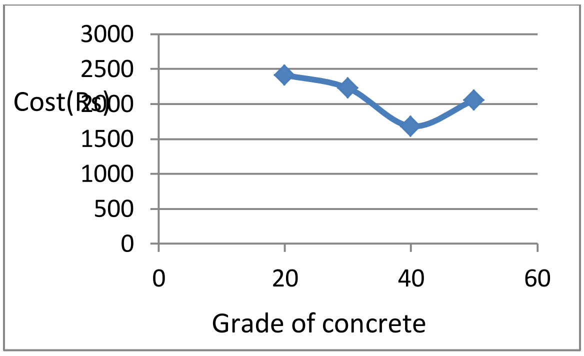

Figure 9:Columns with a load of 1500kN and moment of 120kN-m

From Figure 9, it can be seen that the cost of columns with M40 grade of concrete is the least. The savings in the cost of column made with M20 concrete is 44%.

5.0 Conclusions:

An attempt has been made to optimize the design of Columns subjected to load and uniaxial bending. Eight hundred and sixty four columns were designed. It is found that if the designers follow the traditional techniques, the increase in the cost between the traditional design and optimal design could be as high as 50%. It is also found that the grade of concrete has an impact on the cost of RC columns. It is found that M40 grade of concrete is economical for columns.

6.0 References:

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