OPTIMUM DESIGN OF RC COLUMNS

Rahul Gupta[1], Jagbir Singh[2]

1. GNDEC, Ludhiana, India
2. GNDEC, Ludhiana, India

ABSTRACT. With the ever growing population, diminishing space, surging inflation and limited resources, optimization has become critically important in the field of structural engineering. Since RC frames are the most commonly built structures so the present research work is concentrated towards minimizing the cost of columns - important structural components of a given RCC frame. The computer program so developed is user adaptive as it uses simple tools like STAAD.Pro, MS-Excel and MATLAB. The program has been developed to optimize various types of columns including those under bi-axial loading as well as the slender ones, and the codal provisions of IS 456:2000 have been invoked for the purpose. A meta-heuristic technique based on Fermat's principle called Improved Ray Optimization (IRO) is implied for optimization of columns. Different frames are considered to check the soundness of the technique, and results reported are found to be encouraging. The optimum result also provides information about the structural detailing which gives diameter and arrangement of rebars for all the columns present in a model.

Keywords: Improved Ray Optimization, RC Columns under biaxial loading, Slender RC Columns, STAAD.Pro.

Rahul Gupta, M Tech., research scholar, Department of Civil Engineering, Guru Nanak Dev Engineering College, Ludhiana, India. His research interest includes structural designing and optimization.

Dr. Jagbir Singh, Professor, Department Civil Engineering, Guru Nanak Dev Engineering College, Ludhiana, India. His research interest includes concrete technology and structural optimization.

INTRODUCTION

The economic growth of a nation directly depends upon the level of infrastructure it has. Infrastructure development has been and will remain as main agenda for all the developing countries. Development of infrastructure involves huge cost and the management of the resources allocated for a project is a critical job. It is desired to use optimally the resources so that the money saved can be utilized somewhere else. Nowadays, the RC buildings are being widely constructed as part of Real-Estate projects or government funded infrastructure projects. The utmost utilization of resources in order to save money is the priority of every builder. The research is carried out to develop an optimization program that can utilize the columns present in a RC structure such that after optimization algorithm completes its process, it provides user; the optimized sections which when adopted reduces the cost of the RC structure when compared with its earlier cost coming from initial allotted sections without compromising its safety requirements.

The optimization algorithm written for optimizing columns is based on the literature by Kaveh [11]. The optimization algorithm uses a technique named, Improved Ray Optimization (IRO). The technique adopted for the purpose is meta-heuristic and is based on Fermat's Principle of light rays. It is validated by the feeding some standard benchmark functions and the values obtained are accurate. The comparison of the standard benchmark values of the functions with that reported by the algorithm is presented in the Table 1. The inputs needed by the design algorithm to work like reactions, initial sectional dimensions, etc. are provided after analyzing the RC structure. The analysis of the RC structures is carried out in STAAD.Pro and the analysis results are transferred from the STAAD to Excel using Visual Basics for Application language. The analysis data present in the Excel is easily read by the MATLAB application. The design algorithms written in MATLAB provide the structural detailing of all columns present in RC frame. Important practical implications like availability of particular range of diameter of bars, type of formwork available on site, restriction on size of sections by architects etc. are taken into consideration while making the optimization algorithm. The optimization program works on bi-axial as well as slender columns.

Table 1 Comparison of standard benchmark function values versus values obtained from IRO algorithm

S.No.	Function Name	Standard Value	IRO Value
1	Allufi-Pentiny	-0.352	-0.352
2	Becker and Lago	0.000	0.000
3	Camel	-1.032	-1.032
4	Cb3	0.000	0.000
5	Goldstein and Price	3.000	3.000

DESIGN PROBLEM

A 3-D RC regular frame is taken up and the optimization program made using IRO technique is applied on it. The model is prepared in STAAD.Pro V8i. Different layouts and geometrical specifications have been shown in the following Figures.

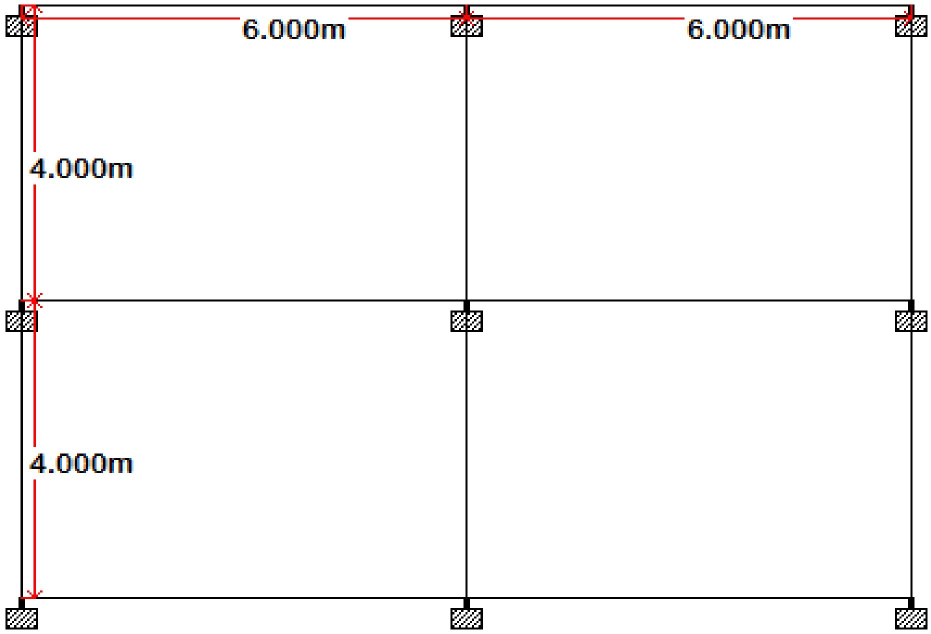

Figure 1 Plan of 3-D Regular Frame

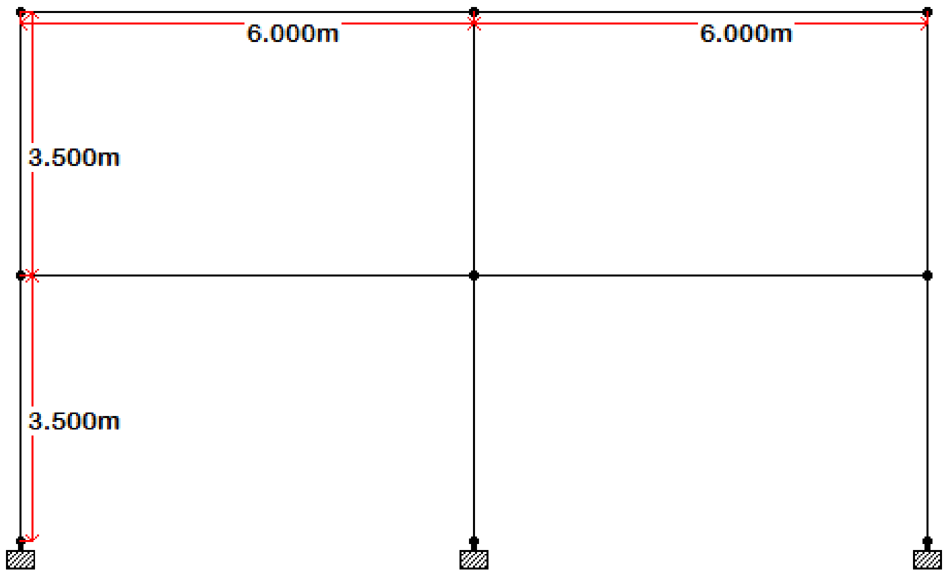

Figure 2 Elevation of 3-D Regular Frame

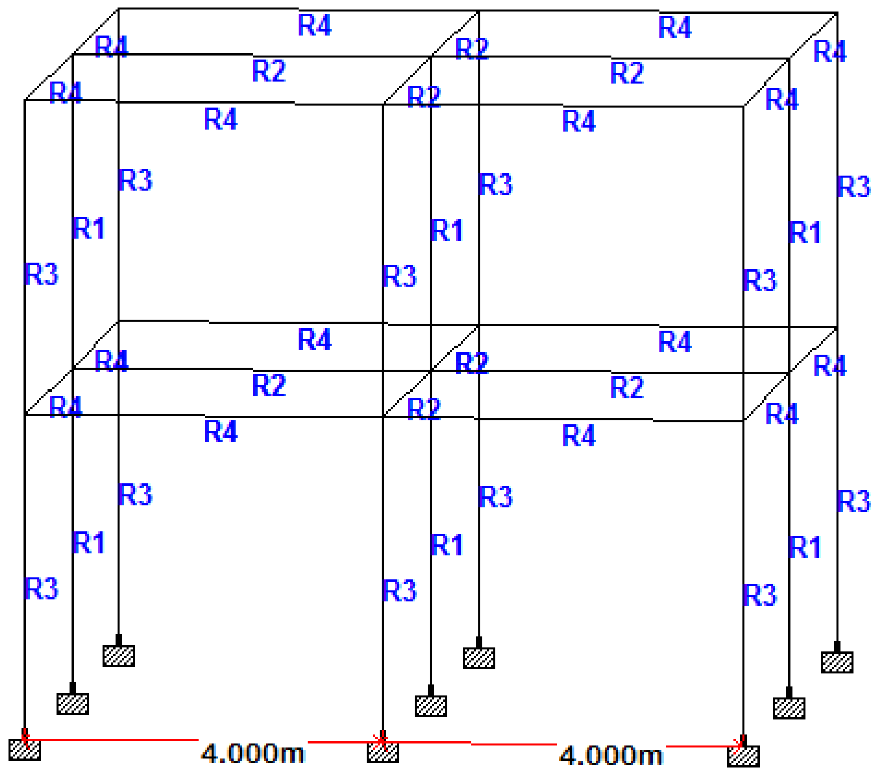

Figure 3 Section Properties of 3-D Regular Frame

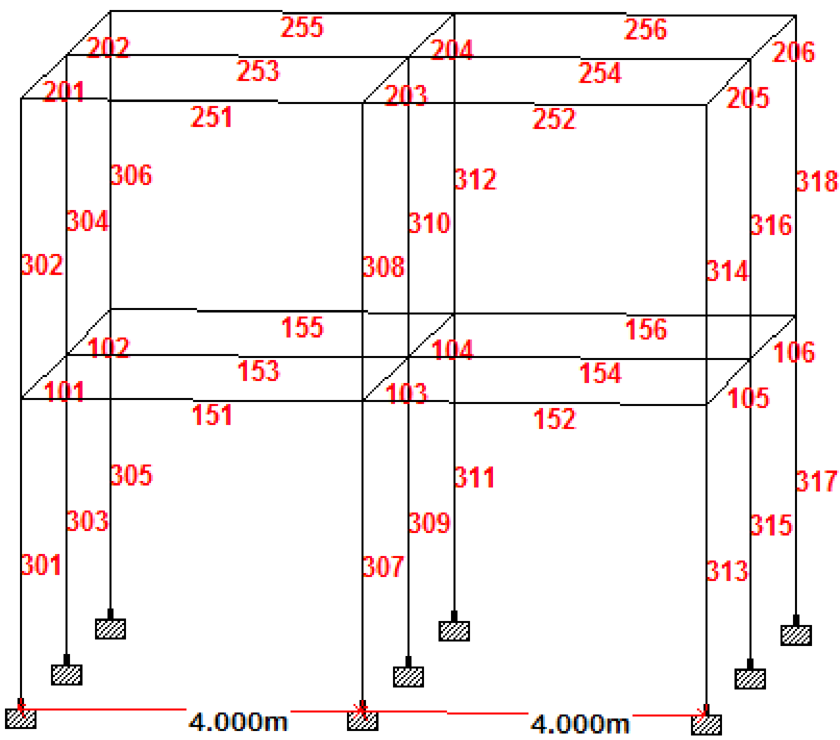

Figure 4 Member Numbers of 3-D Regular Frame

The loading on the RC frame consists of uniform dead load of 7 kN/m^2 on slabs and a uniformly distributed load of 15 kN/m on all the beams. Live load considered is 2 kN/m^2 on all the slabs. The frame is subjected to earthquake loads as per code IS1893:2002. The site conditions for earthquake analysis are zone IV, soil is medium type, damping as 5% and response reduction factor for the frame to be 5. The grade of steel and concrete used is Fe415 and M25 respectively. The load combinations considered for analysis are as per IS456:2000. The details of sections used for columns and beams are given **Error! Not a valid bookmark self-reference.**. The column sections are represented by property name 'R1' and 'R3'. All the columns taken in the study are short columns.

Table 2 Dimensions of Sections for 3-D Regular Frame

S.No.	Section Name	Depth D (mm)	Width b (mm)
1	R1	325	325
2	R2	375	300
3	R3	350	350
4	R4	300	300

RESULTS AND DISCUSSION

The minimum cost obtained corresponding to altered column sections in RC frame after optimization is completed is shown in Table 3. Also, the comparison of detailing given by the STAAD.Pro software and that by the optimization program has been shown in the

Table 4.

Table 3 Comparison of Optimised Sections with STAAD for 3-D Regular Frame

Section Name	STAAD	Present Study
	Depth x Width in mm	Depth x Width in mm
R1	325 x 325	350 x 310
R3	350 x 350	385 x 385
Total Cost (₹)	254533	233132

The minimum cost posted by optimisation program is ₹ 233132 which is 8.4 % less than that of cost given by STAAD.Pro software. The number of analysis performed by the optimisation algorithm is 100.

Table 4 Comparison of detailing of columns with STAAD.Pro for 3-D Regular Frame

S.No.	Member	STAAD		IRO	
		Dxb (mm)	Rebars	Dxb (mm)	Rebars
1	301	350 x 350	16-12	385 x 385	6-25
2	302	350 x 350	24-16	385 x 385	6-25

3	303	325 x 325	20-12	350 x 310	4-20 + 2-16
4	304	325 x 325	20-12	350 x 310	4-20 + 2-16
5	305	350 x 350	16-12	385 x 385	6-25
6	306	350 x 350	24-16	385 x 385	6-25
7	307	350 x 350	12-16	385 x 385	6-25
8	308	350 x 350	24-16	385 x 385	6-25
9	309	325 x 325	16-16	350 x 310	6-20 + 2-16
10	310	325 x 325	16-12	350 x 310	6-20 + 2-16
11	311	350 x 350	12-16	385 x 385	6-25
12	312	350 x 350	24-16	385 x 385	6-25
13	313	350 x 350	16-12	385 x 385	6-25
14	314	350 x 350	24-12	385 x 385	6-25
15	315	325 x 325	20-12	350 x 310	4-20 + 2-16
16	316	325 x 325	20-12	350 x 310	4-20 + 2-16
17	317	350 x 350	16-12	385 x 385	6-25
18	318	350 x 350	24-16	385 x 385	6-25

CONCLUSIONS

Optimum cost of the RC frames reported in the research paper is the least optimum cost of the columns achieved by the optimization program for a fixed search space and variable number of analysis. The optimum cost is found when number of agents are 10 and number of iteration are 10. The total number of analysis performed by optimization algorithm is 100. In comparison to the results provided by the STAAD.Pro, the optimization program makes the RC columns present in the structure nearly 8% cheaper. The column optimized in the research is checked again in STAAD.Pro software after replacing the size the sections provided earlier with that of optimum sections obtained. The sections of the columns found to be appropriate for taking the applied loads.

STAAD.Pro software doesn’t provide variable diameter for rebars at a section which many a times increases the gap between area of steel provided versus area of steel required. But, the detailing provided by the optimization program has variable diameters used at a section. The detailing provided by the optimization program is continuous for continuous columns whereas the STAAD.Pro doesn’t provide such facility.

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