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Particle Swarm Optimization for Design of Beam

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***Abstract*—Particle Swarm Optimization is an optimization technique emulates from social behaviour i.e. birds flocking, fish schooling and bee's behaviour and it is also related to A-life i.e. artificial life (human life). It has wide range of applications in almost every field. In this paper we are applying this technique to Civil Engineering field for designing different types of beam loaded with UDL and supported with different support conditions i.e. simply support, cantilever and fixed support for obtaining optimal quantities of area of steel, moment of resistance and shear stress. With the help of PSO algorithm, MAT-LAB coding is formulated. Area of steel, Moment of resistance and Shear Stress obtain with the help of PSO model is compared with the results obtain by different computational methods i.e. 1) By using IS 456-2000 with manual calculations by rounding off values; 2) Using IS 456-2000 with manual calculations without rounding off values, And 3) Excel sheet calculation. (*Abstract*)**

Keywords*—GBEST – Global Best, LBEST – Local Best, PSO – Particle Swarm Optimization, R/F – reinforcement *(key words)

I. Introduction

Optimization is the process of obtaining the best result under given circumstances to minimize the efforts required or to maximize the desired benefits of analysis. While designing any structure designer needs to assume some values about properties of materials under safety criteria. There are also a one more criteria, economical criteria. Particle Swarm optimization method helps us to maintain the balance situation in between those criteria‟s. It is related to evolutionary computation, and has ties to both genetic algorithms (GA) and evolutionary programming.

Particle Swarm optimization (PSO) method is proposed by Kennedy and Eberhart (1995). It is obtain from social model that don‟t have leader in their group by studying birds flocking, bee‟s behaviour and fish schooling in particular. Typically, a flock of animal that have no leader will find food by random, follow one of the members of the group that has the closest position with a food source (potential solution). The flock achieves their best condition simultaneously through communication among members who already have a better situation. Animal which has a better condition will inform it to its flocks and the others will move simultaneously to that place. This would happen repeatedly until the best conditions or a food source has discovered.

II. Literature Survey

PSO approach is in use for optimization of nonlinear function, developed by social metaphor. It has ties to A-life, bird flocking, fish schooling, and swarming theory in particular and also related to GA & evolutionary programming. PSO is effectively simple algorithm use for many engineering and scientific research optimization field [1]. In practice mostly we use under-reinforced section design. PSO gives us a design of beam as an under-reinforced section which is safer from design criteria given by IS-456 2000. It also provides economical sectional design of beam with provision of less area of steel as compared to area of steel required by manual calculation by IS456-2000. PSO reduces the efforts required to find the optimal and safe design results with great number of trials [2]. To improve the convergence speed with best quality solution speed of PSO follows the biologically inspired computational search optimization method based on stochastic evolutionary optimization method. To deal with the problems of PSO, basic PSO method is present. Modified variant PSO is use to overcome the defects of basic PSO. Numbers of variants are in use to improve the performance of this method [3,4]. PSO algorithm is use for structural field for optimization with tuning parameters to promote best global/local search for cut off premature convergence. This is an idea method in structural engineering field due to its simplicity in implementation and better ability for optimization with compare to other optimization field [5]. Accordingly „No Free Lunch‟ theorem only single method is not enough for solving optimization

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problem effectively. EPSO is use as an effective and powerful method for solving different types of complex optimization problem without getting trap into local optima [6]. Due to subtraction based solution mechanism diversity in particle population is lost, showing the stagnation behavior and to deal with this problem „Velocity and Position Update" rule is useful [7]. Numbers of iterations get affected due to changes in paradigms. GBEST performs best in medium numbers of iterations while LBEST with two numbers of iterations is most exact [8]. PSO"s performance is not sensitive to population size and has ability to converge toward optimal result. Due to linearly decreasing inertia weight it has lack the global search ability at the run"s end, which fails to find optimal value of complicated problems. By employing self adapting approach this difficulty can be overcome [9]. Studies of human cognitive psychology shows, best planer regulate their strategies with respect to the current state and their perception of the experience from others. From this learning strategies SRPSO is invented, which performs better than other PSO variants with 95% confidence level [10]. Design of beam is a heuristic optimization problem can be solve effectively by proper allocation of constraint based on engineering clauses given by different IS codes with exact objective function. With the help of PSO large size design problems can be solve with this technique with less efforts and effective optimization results [11]. To solve large size complex problems, TSP is use with uncertainty and crossover technique t speed up convergence speed [12]. PSO technique can replace GA and other optimization technique for beam-slab design with perfect solution [13].

III. Methodology

By simulating the social model „B. K. Chakrabarty" has developed a model for Optimal Design of Reinforced Concrete beam for cost optimization. With reference to that model I have created 3 models for design of Reinforced concrete Beam with different support conditions i.e. Simply Support, Cantilever and Fixed respectively loaded with UDL. Algorithm 1 describes the details of algorithm use for simply supported beam formed by using IS Code clauses. Algorithm 2 describes the details of algorithm use for cantilever beam formed by using IS Code clauses for safe design. Algorithm 3 describes the details of algorithm use for fixed beam formed with IS Code design clauses.

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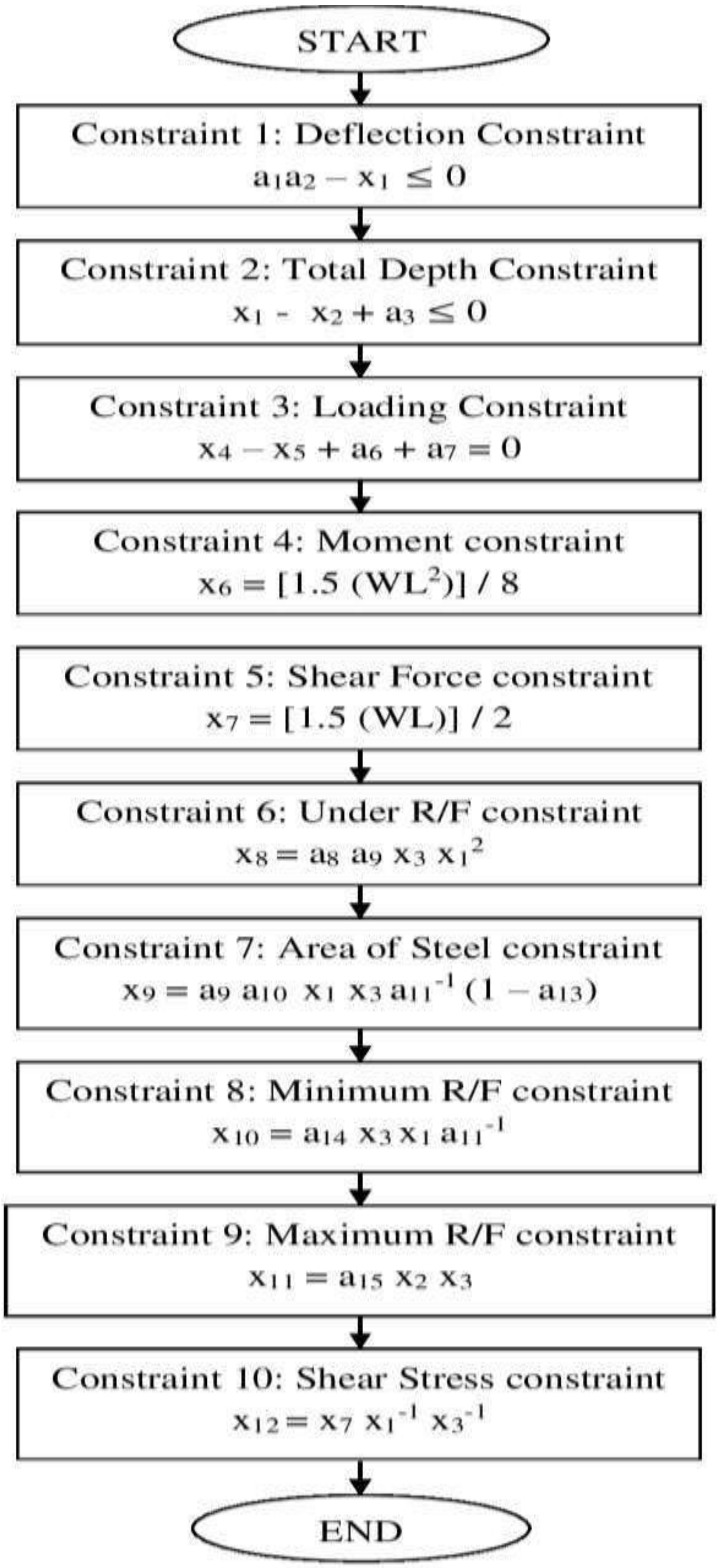

Algorithm 1. Algorithm for Simply Supported Beam

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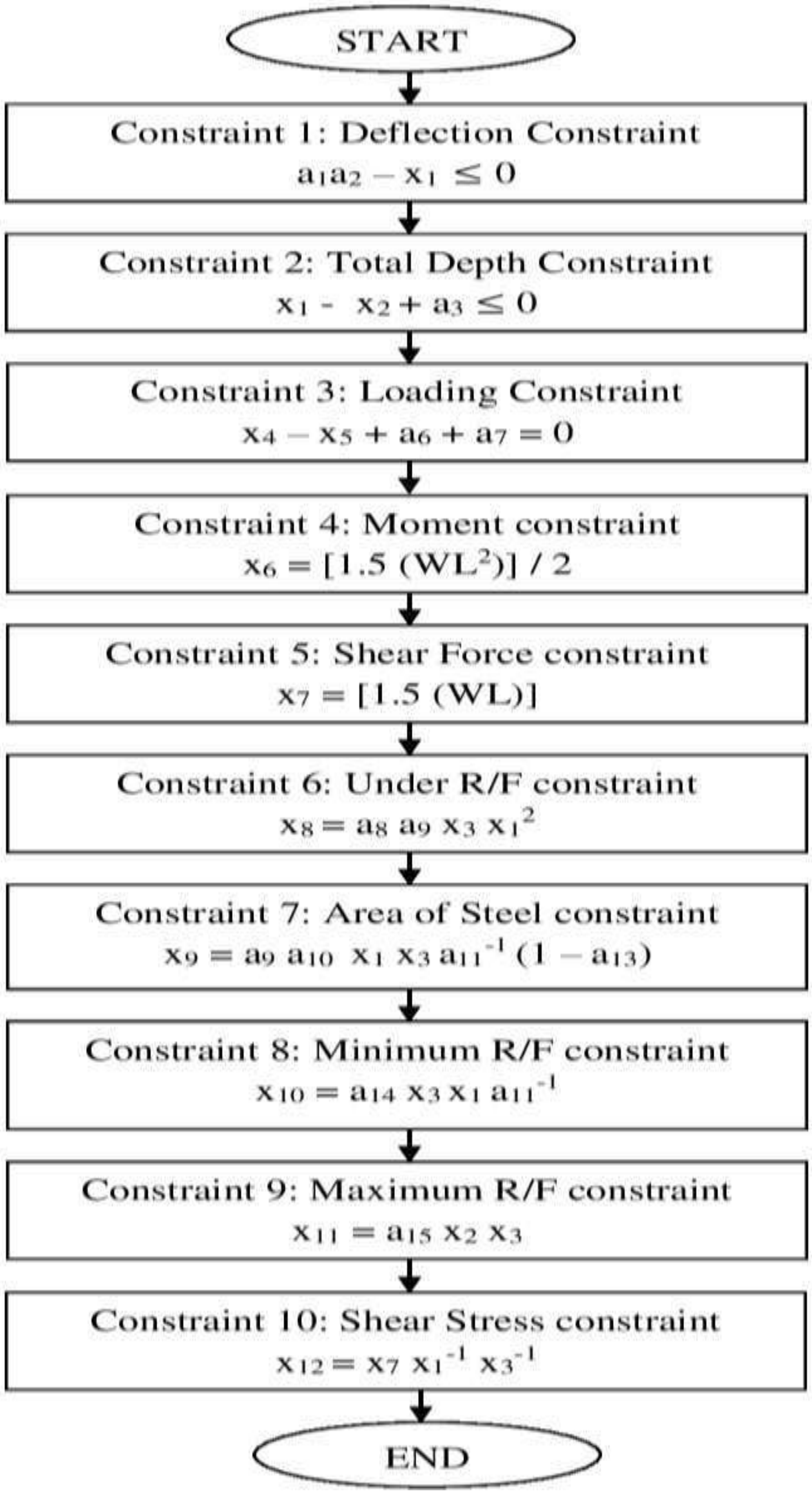

Algorithm 2. Algorithm for Cantilever Beam

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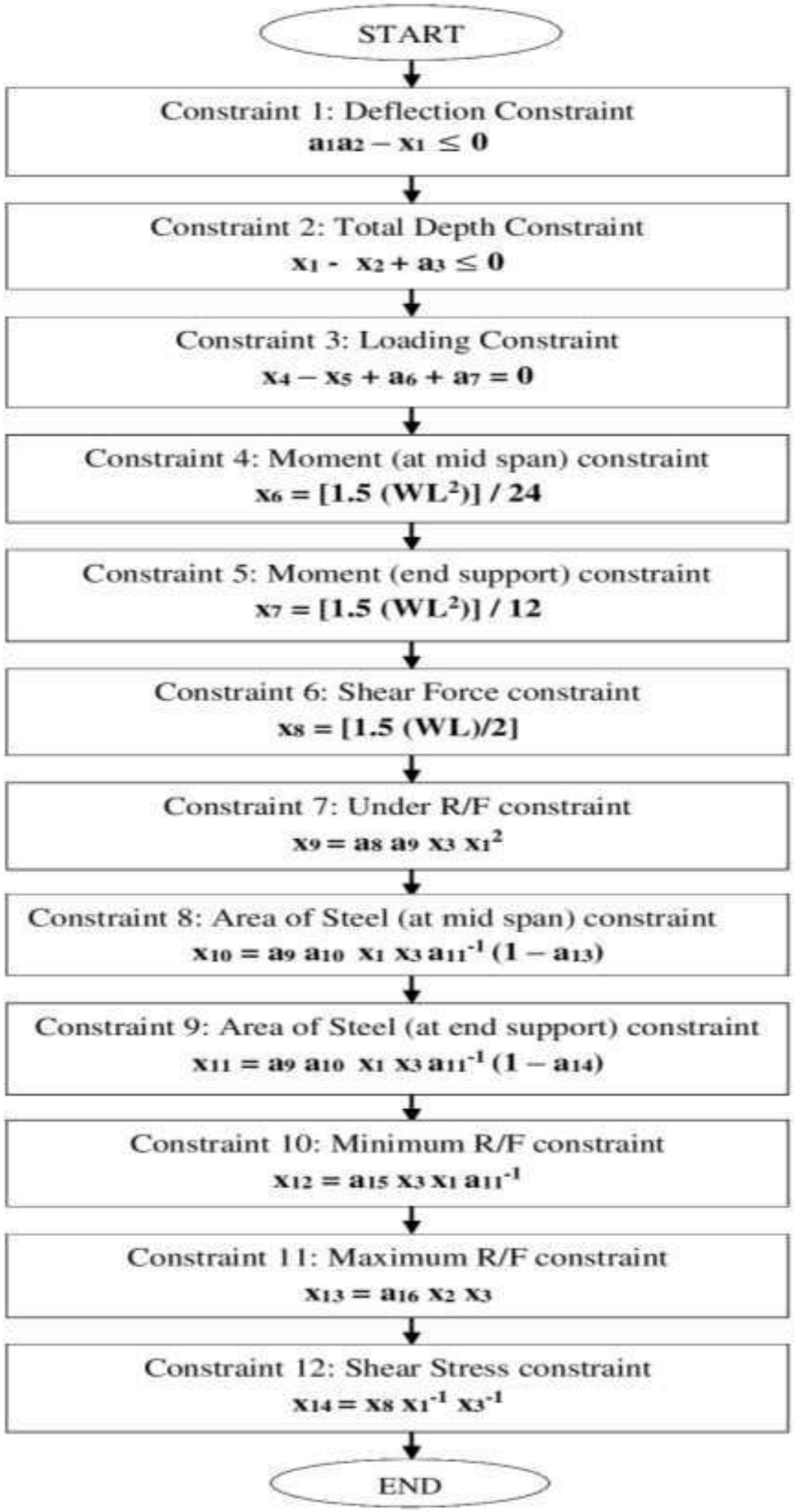

Algorithm 3. Algorithm for Fixed Beam

With the help of above algorithms by collaborating with PSO algorithm, MATLAB algorithm created to find the result by PSO approach.

IV. Results

Results obtained by PSO method is compared with method 1 (manual calculations done using IS456 2000 by rounding off values), method 2 (manual calculations done by using IS456-2000 without rounding off values) and method 3 (Excel sheet calculations). Results obtained are tabulated as follows with units: Area of steel in mm^2, Moment of Resistance in KN·m and Shear Stress in KN/mm^2.

TABLE I. Simply Supported Beam"s Result

Sr. No.	Particular	Method 1	Method 2	Method 3	PSO method
1.	***Area of steel***	338.43	410.84	401.90	330.00
	Moment of Resistance	32.910	31.570	31.000	33.070
	Shear Stress	0.4000	0.4000	0.0000	0.3800
2.	***Area of steel***	331.33	408.06	398.40	320.00
	Moment of Resistance	31.760	30.580	30.000	31.960
	Shear Stress	0.4000	0.4000	0.0000	0.3900
3.	***Area of steel***	327.33	408.64	392.47	315.00
	Moment of Resistance	30.980	29.920	29.000	31.030
	Shear Stress	0.4000	0.5000	0.0000	0.3900
4.	***Area of steel***	482.96	518.75	513.40	477.00
	Moment of Resistance	48.178	47.400	47.000	49.020
	Shear Stress	0.4000	0.4000	0.0000	0.3900
5.	***Area of steel***	475.07	513.64	503.25	470.05
	Moment of Resistance	46.410	45.730	45.000	47.010
	Shear Stress	0.5000	0.5000	0.0000	0.4900
6.	***Area of steel***	471.83	513.42	491.34	462.00
	Moment of Resistance	45.225	44.617	44.000	45.690
	Shear Stress	0.5000	0.5000	0.0000	0.4000
7.	***Area of steel***	598.17	635.99	634.11	582.00
	Moment of Resistance	68.220	67.160	67.000	68.850
	Shear Stress	0.4000	0.4000	0.0000	0.4000
8.	***Area of steel***	586.82	627.83	621.04	575.00
	Moment of Resistance	65.460	64.540	64.000	66.010
	Shear Stress	0.5000	0.5000	0.0000	0.4000
9.	***Area of steel***	602.59	639.70	639.36	592.00
	Moment of Resistance	69.130	68.030	68.000	69.850
	Shear Stress	0.5000	0.5000	0.0000	0.4000
10.	***Area of steel***	722.78	762.85	761.06	715.00
	Moment of Resistance	92.540	91.170	91.000	92.870
	Shear Stress	0.5000	0.5000	0.0000	0.4900
11.	***Area of steel***	735.56	773.68	766.04	728.00
	Moment of Resistance	95.280	93.750	93.000	95.650
	Shear Stress	0.5000	0.5000	0.0000	0.4000
12.	***Area of steel***	707.59	751.12	747.72	699.00
	Moment of Resistance	88.500	87.300	87.000	89.500
	Shear Stress	0.5000	0.5000	0.0000	0.4000
13.	***Area of steel***	687.61	773.67	766.04	690.00
	Moment of Resistance	97.500	93.750	93.000	98.020
	Shear Stress	0.4000	0.4000	0.0000	0.4000
14.	***Area of steel***	673.64	762.85	761.06	666.00
	Moment of Resistance	94.620	91.17	91.000	94.660
	Shear Stress	0.4000	0.4000	0.0000	0.4000
15.	***Area of steel***	652.32	751.12	747.72	650.00
	Moment of Resistance	90.000	87.300	87.000	90.060
	Shear Stress	0.5000	0.5000	0.0000	0.4600
16.	***Area of steel***	873.42	913.87	910.25	860.00
	Moment of Resistance	125.29	123.39	123.00	126.03
	Shear Stress	0.5000	0.5000	0.0000	0.5000
17.	***Area of steel***	900.03	938.59	930.94	900.23
	Moment of Resistance	130.99	128.86	128.00	131.25
	Shear Stress	0.4000	0.4000	0.0000	0.4000

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18.	***Area of steel***	889.87	913.87	910.25	872.00
	Moment of Resistance	124.38	123.39	123.00	124.39
	Shear Stress	0.5000	0.5000	0.0000	0.5000
19.	***Area of steel***	878.09	899.69	892.49	875.09
	Moment of Resistance	120.66	119.75	119.00	121.00
	Shear Stress	0.5000	0.5000	0.0000	0.5000
20.	***Area of steel***	857.49	899.69	892.49	859.49
	Moment of Resistance	121.50	119.75	119.00	121.30
	Shear Stress	0.5000	0.5000	0.0000	0.4000
21.	***Area of steel***	890.88	930.02	929.66	888.00
	Moment of Resistance	129.09	127.04	127.00	129.97
	Shear Stress	0.5000	0.5000	0.0000	0.5000

TABLE II. Cantilever Beam"s Result

Sr. No.	Particular	Method 1	Method 2	Method 3	PSO method
1.	***Area of steel***	226.60	235.75	175.00	220.00
	Moment of Resistance	023.25	22.920	15.000	23.650
	Shear Stress	0.3000	0.2000	0.0000	0.3000
2.	***Area of steel***	216.80	235.59	175.00	212.98
	Moment of Resistance	23.025	22.905	15.000	23.950
	Shear Stress	0.2000	0.3000	0.0000	0.2000
3.	***Area of steel***	329.74	238.45	186.00	319.58
	Moment of Resistance	24.255	23.433	15.000	25.000
	Shear Stress	0.2000	0.3000	0.0000	0.2000
4.	***Area of steel***	392.62	406.84	262.00	385.98
	Moment of Resistance	59.910	58.790	34.000	59.990
	Shear Stress	0.3000	0.3000	0.0000	0.3000
5.	***Area of steel***	402.65	416.90	280.00	398.00
	Moment of Resistance	61.590	60.410	34.000	61.520
	Shear Stress	0.3000	0.3000	0.0000	0.3000
6.	***Area of steel***	389.64	431.93	306.00	369.00
	Moment of Resistance	67.060	62.810	34.000	67.950
	Shear Stress	0.3000	0.3000	0.0000	0.3000
7.	***Area of steel***	66.060	93.400	81.480	65.230
	Moment of Resistance	4.5500	4.3800	3.0000	5.0300
	Shear Stress	0.3000	0.4100	0.0000	0.2000
8.	***Area of steel***	67.570	94.270	80.230	60.000
	Moment of Resistance	4.6870	4.4900	3.0000	4.9500
	Shear Stress	0.2000	0.3000	0.0000	0.2000
9.	***Area of steel***	56.410	90.980	79.640	59.520
	Moment of Resistance	4.9700	4.3800	3.0000	5.0200
	Shear Stress	0.2000	0.3000	0.0000	0.2000
10.	***Area of steel***	111.43	151.72	118.84	106.00
	Moment of Resistance	11.600	10.870	8.0000	11.870
	Shear Stress	0.3000	0.3000	0.0000	0.3000
11.	***Area of steel***	108.05	153.83	118.39	101.00
	Moment of Resistance	12.080	11.090	8.0000	12.120
	Shear Stress	0.2000	0.3000	0.0000	0.2000
12.	***Area of steel***	105.53	151.72	118.83	103.00
	Moment of Resistance	11.770	10.870	8.0000	11.980
	Shear Stress	0.2000	0.3000	0.0000	0.2000
13.	***Area of steel***	106.83	152.91	118.46	104.00
	Moment of Resistance	11.930	10.990	8.0000	12.000
	Shear Stress	0.2200	0.3200	0.0000	0.2000
14.	***Area of steel***	114.50	155.09	117.84	112.00
	Moment of Resistance	12.240	11.210	8.0000	12.950
	Shear Stress	0.2000	0.3000	0.0000	0.2000
15.	***Area of steel***	114.00	153.88	118.14	109.00
	Moment of Resistance	11.900	11.098	8.0000	11.980
	Shear Stress	0.2000	0.3000	0.0000	0.3000
16.	***Area of steel***	290.60	316.85	219.00	279.00
	Moment of Resistance	39.840	38.330	24.000	40.010
	Shear Stress	0.3000	0.3000	0.0000	0.2900
	Area of steel	299.15	313.75	219.00	285.00

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17.	***Moment of Resistance***	38.790	37.980	24.000	39.000
	Shear Stress	0.3000	0.3000	0.0000	0.3000
18.	***Area of steel***	297.69	323.81	233.00	282.00
	Moment of Resistance	40.898	39.280	24.000	41.030
	Shear Stress	0.3000	0.3000	0.0000	0.2800
19.	***Area of steel***	305.99	320.56	233.00	302.00
	Moment of Resistance	39.770	38.910	24.000	39.990
	Shear Stress	0.3000	0.3000	0.0000	0.3000
20.	***Area of steel***	287.20	323.81	233.00	276.00
	Moment of Resistance	41.600	39.280	24.000	41.750
	Shear Stress	0.2000	0.3000	0.0000	0.2000
21.	***Area of steel***	284.91	334.61	255.00	280.00
	Moment of Resistance	44.530	40.730	24.000	44.980
	Shear Stress	0.2000	0.3000	0.0000	0.2000

TABLE III. Fixed Beam"s Result

Sr. No	**Particular**	**Method 1**	**Method 2**	**Method 3**	**PSO method**
1.	***Area of steel at mid span***	141.32	121.97	117.00	141.02
	Area of steel at support	216.76	257.06	256.52	210.78
	Moment of Resistance at mid span	10.970	10.520	10.000	11.030
	Moment of Resistance at support	21.940	21.040	21.000	22.000
	Shear Stress	0.4000	0.4000	0.0000	0.3000
2.	***Area of steel at mid span***	122.89	118.80	116.47	120.66
	Area of steel at support	210.93	252.46	247.00	201.00
	Moment of Resistance at mid span	10.590	10.190	10.000	10.980
	Moment of Resistance at support	21.170	20.390	20.000	21.200
	Shear Stress	0.4000	0.4000	0.0000	0.4000
3.	***Area of steel at mid span***	110.60	116.80	104.82	101.00
	Area of steel at support	207.36	249.93	236.36	198.00
	Moment of Resistance at mid span	10.330	9.9700	9.0000	10.980
	Moment of Resistance at support	20.660	19.950	19.000	21.060
	Shear Stress	0.4000	0.5000	0.0000	0.4000
4.	***Area of steel at mid span***	150.75	152.981	141.00	140.00
	Area of steel at support	304.24	323.32	316.46	298.03
	Moment of Resistance at mid span	16.060	15.800	15.000	16.950
	Moment of Resistance at support	32.120	31.600	31.000	32.980
	Shear Stress	0.4000	0.4000	0.0000	0.3000
5.	***Area of steel at mid span***	140.35	148.38	145.92	142.29
	Area of steel at support	296.42	316.09	310.44	297.00
	Moment of Resistance at mid span	15.470	15.240	15.000	15.980
	Moment of Resistance at support	30.940	30.480	30.000	30.980
	Shear Stress	0.5000	0.5000	0.0000	0.4000
6.	***Area of steel at mid span***	137.34	145.48	136.47	140.00
	Area of steel at support	291.75	312.14	303.19	293.52
	Moment of Resistance at mid span	15.075	14.870	14.000	15.080
	Moment of Resistance at support	30.150	29.740	29.000	30.250
	Shear Stress	0.5000	0.5000	0.0000	0.5000
7.	***Area of steel at mid span***	178.04	186.12	182.80	175.00
	Area of steel at support	374.89	394.59	386.96	370.00
	Moment of Resistance at mid span	22.740	22.380	22.000	22.980
	Moment of Resistance at support	45.480	44.770	44.000	45.850
	Shear Stress	0.4000	0.4000	0.0000	0.4000
8.	***Area of steel at mid span***	151.56	179.89	175.38	150.32
	Area of steel at support	363.99	384.40	384.20	358.65
	Moment of Resistance at mid span	14.550	21.510	21.000	14.980
	Moment of Resistance at support	43.640	43.020	43.000	43.920
	Shear Stress	0.5000	0.5000	0.0000	0.4500
9.	***Area of steel at mid span***	181.88	188.24	182.40	180.09
	Area of steel at support	378.69	398.22	394.78	361.00
	Moment of Resistance at mid span	23.040	22.670	22.000	23.090
	Moment of Resistance at support	46.090	45.350	45.000	47.020
	Shear Stress	0.5000	0.4000	0.0000	0.4000
10.	***Area of steel at mid span***	213.32	221.60	218.61	210.65

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	Area of steel at support	450.69	471.12	464.28	432.00
	Moment of Resistance at mid span	30.850	30.390	30.000	31.030
	Moment of Resistance at support	61.696	60.780	60.000	62.030
	Shear Stress	0.5000	0.5000	0.0000	0.5000
11.	***Area of steel at mid span***	218.95	227.20	225.29	211.00
	Area of steel at support	460.95	480.98	476.66	455.22
	Moment of Resistance at mid span	31.750	31.250	31.000	31.850
	Moment of Resistance at support	63.500	62.500	62.000	63.950
	Shear Stress	0.5000	0.4000	0.0000	0.4000
12.	***Area of steel at mid span***	205.02	213.40	216.63	202.00
	Area of steel at support	436.29	457.47	455.66	425.00
	Moment of Resistance at mid span	29.500	29.100	29.000	29.890
	Moment of Resistance at support	59.000	58.200	58.000	59.630
	Shear Stress	0.5000	0.5000	0.0000	0.4000
13.	***Area of steel at mid span***	230.00	227.20	225.29	225.00
	Area of steel at support	435.20	480.98	476.66	430.00
	Moment of Resistance at mid span	32.500	31.250	31.000	31.890
	Moment of Resistance at support	65.000	62.500	62.000	65.060
	Shear Stress	0.4000	0.4000	0.0000	0.4000
14.	***Area of steel at mid span***	211.99	221.60	218.61	215.33
	Area of steel at support	424.58	471.12	464.28	439.00
	Moment of Resistance at mid span	31.540	30.390	30.000	31.600
	Moment of Resistance at support	63.080	60.780	60.000	63.980
	Shear Stress	0.4000	0.4000	0.0000	0.4000
15.	***Area of steel at mid span***	193.36	213.40	212.63	190.00
	Area of steel at support	407.82	457.47	455.66	400.00
	Moment of Resistance at mid span	30.000	29.100	29.000	31.000
	Moment of Resistance at support	60.000	58.200	58.000	61.000
	Shear Stress	0.5000	0.5000	0.0000	0.4000
16.	***Area of steel at mid span***	257.96	266.36	265.47	246.00
	Area of steel at support	544.92	565.54	563.52	522.00
	Moment of Resistance at mid span	41.760	41.130	41.000	41.980
	Moment of Resistance at support	83.530	82.260	82.000	83.980
	Shear Stress	0.5000	0.5000	0.0000	0.4000
17.	***Area of steel at mid span***	269.54	277.13	270.70	275.00
	Area of steel at support	564.91	585.48	578.55	567.00
	Moment of Resistance at mid span	43.640	42.950	42.000	43.980
	Moment of Resistance at support	87.280	85.910	85.000	88.010
	Shear Stress	0.4000	0.4000	0.0000	0.4000
18.	***Area of steel at mid span***	262.15	266.36	265.47	252.00
	Area of steel at support	555.12	565.54	563.52	541.00
	Moment of Resistance at mid span	41.460	41.130	41.000	41.980
	Moment of Resistance at support	82.930	82.260	82.000	83.000
	Shear Stress	0.5000	0.5000	0.0000	0.4000
19.	***Area of steel at mid span***	255.05	259.23	252.99	248.00
	Area of steel at support	542.24	552.87	546.31	525.00
	Moment of Resistance at mid span	40.220	39.910	39.000	40.590
	Moment of Resistance at support	80.440	79.830	79.000	80.920
	Shear Stress	0.5000	0.5000	0.0000	0.4000
20.	***Area of steel at mid span***	250.86	259.23	252.99	255.32
	Area of steel at support	531.87	552.87	546.31	539.11
	Moment of Resistance at mid span	40.500	39.910	39.000	41.000
	Moment of Resistance at support	81.000	79.830	79.000	81.090
	Shear Stress	0.5000	0.5000	0.0000	0.5000
21.	***Area of steel at mid span***	265.20	273.50	271.19	262.00
	Area of steel at support	558.39	578.71	573.42	550.00
	Moment of Resistance at mid span	43.030	42.340	42.000	43.090
	Moment of Resistance at support	86.060	84.690	84.000	86.090
	Shear Stress	0.5000	0.5000	0.0000	0.5000

With the help of above algorithms by collaborating it with PSO algorithm, MATLAB algorithm created to find the result by PSO approach.

V. Conclusion

From the above tabulated form results following conclusions are drawn

A. PSO method yields less area of steel as compared to other three methods i.e. manual calculations by rounding off values with IS456-2000, manual calculation without rounding off values with IS456-2000 and Excel sheet calculation though Moment of resistance for the same case by PSO method is more than other methods due to PSO algorithm.
B. Shear stress calculated by PSO method is also on safer side as compared to clauses of shear stress given by IS456-2000.
C. PSO proves to be best method for optimizing beam design with satisfying all the design clauses.

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Particle Swarm Optimization correlates artificial life (A-life), birds flocking, fish schooling and swarming theory in particular.

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