PARAMETRIC STUDY OF OPTIMIZED REINFORCED CONCRETE CIRCULAR PIER USING MIDAS AND MATLAB

[1]PG Trivedi, [2]SP Chandresha, [3]KB Parikh

[1]Post-graduate student, [2]Professor, [3]Head of department

[123] Applied Mechanics Department, Government Engineering College, Dahod, Gujarat, India,

Abstract: ***The construction of a bridge is a very expensive process and the pier is the main component in terms of distributing the loads from superstructure to foundation. Loads and load distribution highly depend on the shapes of the pier. There are various shapes of piers that are used in construction. The primary goal of this study is to find the optimized section and check the shape effect on analysis that has been carried out using MIDAS. In this study; first, the optimization of the circular pier is done with the help of MATLAB then a comparison has been made for various variables found from the process. After that analysis was run using MIDAS to check the buckling factor, displacement, and stresses. Then after the square shape has been taken and the above steps followed. The conclusion has been made up from both the shapes and it suggests that circular pier has better resistance to water pressure, has also good resistance to displacement and stress. It also reduces the volume required for concrete and the area of steel from its original section.***

Key Words: MATLAB, MIDAS, genetic algorithm, optimization, pier

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I. INTRODUCTION:

Piers are the vital structural component that spans at a halfway point and performs main functions i.e. transferring vertical loads to the foundations and resisting horizontal forces. Piers are designed to regulate vertical loads; it is becoming essential to design piers to resist larger horizontal loads produced due to seismic events. Piers are the compression members and their failure leads to risk the whole structure. Optimization is the act of finding the best result under given conditions. Optimization of pier means reducing its mass, which results in the reduction of self-weight of the pier. Wide applications of software like MATLAB in the design engineering problems where a specific goal is to minimize or maximize a certain parameter. Design engineers need to design buildings, bridges, dams, and other structures, in these design processes it is necessary to reach maximum protection or minimum rate or both, so in these cases, optimization algorithms have wide applications. Optimization technique plays the main role in reaching economy, which is an important factor next only to safety. GA is well-known for handling global optimization problems when several local optimal are presenting a non-continuous fitness landscape. GAs is a type of optimization algorithms that used to find the optimum solution to a given computational problem that maximizes or minimizes a specific function and these are function optimizers.

II. LITERATURE REVIEW

Francisco et al Works on the economic optimization of reinforced concrete bridge pier with hollow rectangular section and analyzes the efficiency of three heuristic algorithm. In this paper, new Ant Colony Optimization is compared with the Threshold Acceptance algorithm and Genetic Algorithm. The ACO–GA–TA algorithms yield similar results, although the TA heuristic six outperforms ACO and GA algorithms in terms of best, mean, and computing times. Regarding population algorithms, the ACO is more robust than the GA algorithms in terms of mean results while the GA outperforms ACO algorithms in terms of best results[1]

Wang Jian works on analyzing the three different piers i.e., Reinforced Concrete Bridge Pier, Concrete filled steel tube, Steel tube, and analyze those Piers through MIDAS. In this paper, the researcher made a study by gradually increasing the load on 24 points to check the stress of three types of the pier. The result indicates that the increase of maximum compressive force in steel-reinforced concrete is much less than the increase in the concrete-filled steel structure[2]

Govindaraj et al optimize reinforced concrete frames using a genetic algorithm with the help of FORTRAN. The objective function of the research is to find the minimum cost of the frame that includes the cost of concrete, steel, and formwork of the beam and column. They reported a 7.98% cost reduction on a two-bay six-story RC plane frame. There are 34.19% cost improvements in columns when using genetic algorithms[3]

Mohamed et al study a three-dimensional finite element model for bridge piers constructed out of segmental precast post-tensioned concrete-filled fiber-reinforced polymer tubes (PPT-CFFTs). The model was first validated against the results of experimental investigations on two PPT-CFFT piers. Then, the effects of the applied post-tensioning force, load combination, pier aspect ratio, pier size, pier cross-sectional diameter size, and pier confinement on the lateral performance of the piers were investigated. Two sets of piers were investigated in this parametric study: set ‘‘L’’ including piers that have a large diameter of 1220 mm while set ‘‘S’’ including piers that have a small diameter of 610 mm. For the same pier height, increasing the pier diameter size significantly increased the pier shear stress capacity and has minimal effects on the deformation capacity of the pier[4]

Amit et al analyze the integral pier by changing its parameters to get the optimum result that could help the engineers to finalize the shape and size of the pier by using MIDAS Civil Software. They made 12 different cases of the pier with different widths and thicknesses and kept height constant. They concluded that stiffness of member increases the force in integral structure is also get increases and force of each member also increase[5]

III. MODELLING AND ANALYSIS

Current work includes the parametric study i.e. Diameter of the pier, Load of the pier, Bending Moment, Area of steel, Volume of concrete, Deflection, Stresses, Buckling Mode shapes. MATLAB has carried out the calculation of mathematical parameters. To carry out a structural optimization structural analysis program is coded in MATLAB and optimized with the help of the optimization toolbox by assigning Genetic optimization as a toolbox option. After finding the optimized section, the Parameter of that section is calculated with the help of MATLAB script. To create 3D models and to carry out various analyses MIDAS Civil is used.

In this problem, the Volume of the Pier is taken as the objective function. To satisfy that objective by maximum protection some constraints and variables are taken as follows.

- Non-variables are Height of pier, Grade of concrete, Grade of the slab.
- Design variables in this study will be Diameter of the pier, axial load and bending moment in the pier, Longitudinal reinforcement, Transverse reinforcement, Spacing of bars.
- Constraint under evaluation is minimum reinforcement, ultimate load carrying capacity, section capacity, the width of a column, the diameter of bars, shear check, Flexure check.

In this work, a pier with a pier cap having a diameter of 2.6 meters and a height of 8.5 meters is carried out for analysis and optimization purposes.

Table 1: Pre-assigned variables

Radius of pier	1.3 m
Height of pier	8.5 m
Concrete grade	30 N/mm^2
Steel grade	500 N/mm^2
Dead Load From Superstructure	8560.0 kN
Dead Load due to pier cap	702.00 kN
Live Load	2564.55 kN
Lateral force due to frictional resistance of bearings	138.36 kN
Superstructure	642.00 kN
Pier cap	52.65 kN
Pier stem	81.23 kN

```
function f = DP_Pier_fun(x)

xl=x(1);%Radius of pier

h = 8.5;

f = pi*xl^2*h; %volume of pier
```

Fig -1: Objective function

Editor - C:\Users\Parth\Documents\MATLAB\DP_Pier_cons.m

DP_Pier_cons.m | DP_Pier_fun.m | optimized_section.m | DP_square_Pier_cons.m | DP_square_Pier_fun.m | Optimize_square.m

```
function [c, ceq] = DP_Pier_cons(x)

%variables

x1= x(1); %radius of pier m
Dc = (x1*2)-80-40;%diameter upto line of reinforcement
Sacc = 7.5;%Allowable comp. stress in concrete in direct compression
Sacb = 10;%Allowable compressive stress in concrete in flexure
m = 10;%Modular ratio
h = 8.5; %height of pier m
fck = 30;%concrete grade N/mm^2
fy = 500;%steel grade N/mm^2
w_conc = 24;%unit weight of concrete kN/m^3
w_water = 10; %unit weight of water kN/m^3

% Load Calculation
```

Fig -2: Constraint function

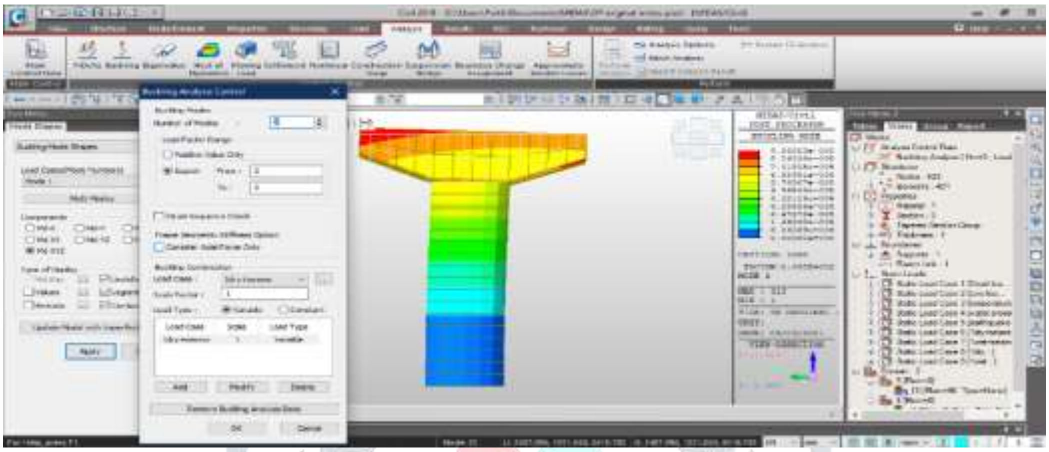

Fig -3: Buckling Analysis of circular section

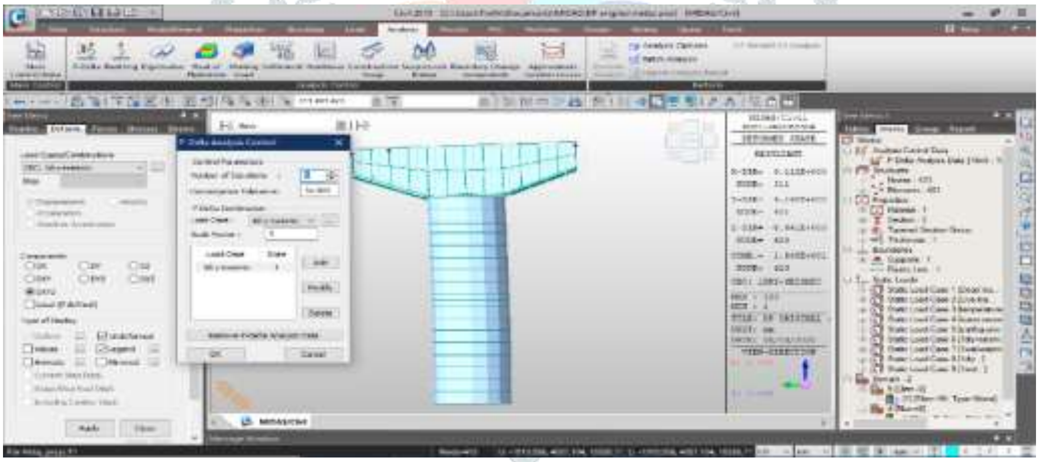

Fig -4: P-Delta analysis of circular section

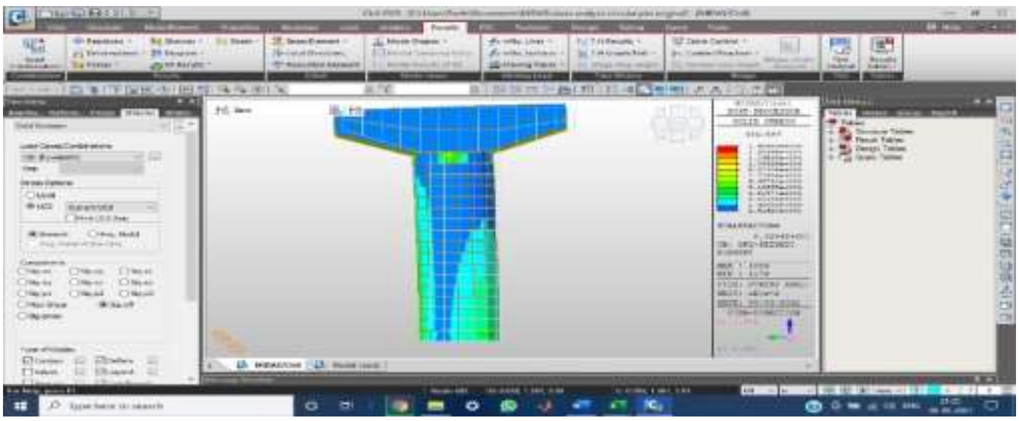

Fig- 5: Static analysis of circular section

IV. RESULTS

- **Circular section result**

Table -2: Percentage comparison of original and optimized circular section

Variable	Circular Section		% comparison
	Actual section	Optimized section	
Radius	1.3 m	1.115 m	16.59%
Veticle load	13686 kN	13399 kN	2.14%
Load @ x- direction	1641.8 kN	1589.4 kN	3.30%
Load @ y- direction	1701.9 kN	1660.7 kN	2.48%
Moment @ x-direction	16044 kN/m^2	15769 kN/m^2	1.74%
Moment@ y- direction	16794 kN/m^2	16619 kN/m^2	1.05%
Area of concrete	5154400 mm^2	3802100 mm^2	35.57%
Gross-area	5309300 mm^2	3905700 mm^2	35.94%
Steel area	154880 mm^2	103620 mm^2	49.47%
Asc/meter	18221 mm^2	12191 mm^2	49.46%
Pt	2.9171	2.653	9.95%
Column bar provided	24	16	50.00%
Long. Bar spacing	54.1667 mm	69.6875 mm	-22.27%
Total long. steel weight	1532.2 kN	1021.5 kN	50.00%
Trans. Bar provided	58	58	0.00%
Total Trans. steel weight	197.4135 kN	167.4497 kN	17.89%
Steel weight	1729.6 kN	1188.9 kN	45.48%
Steel cost	103780	71335	45.48%
Concrete cost	240970	177750	35.57%
Total cost	344750	249080	38.41%

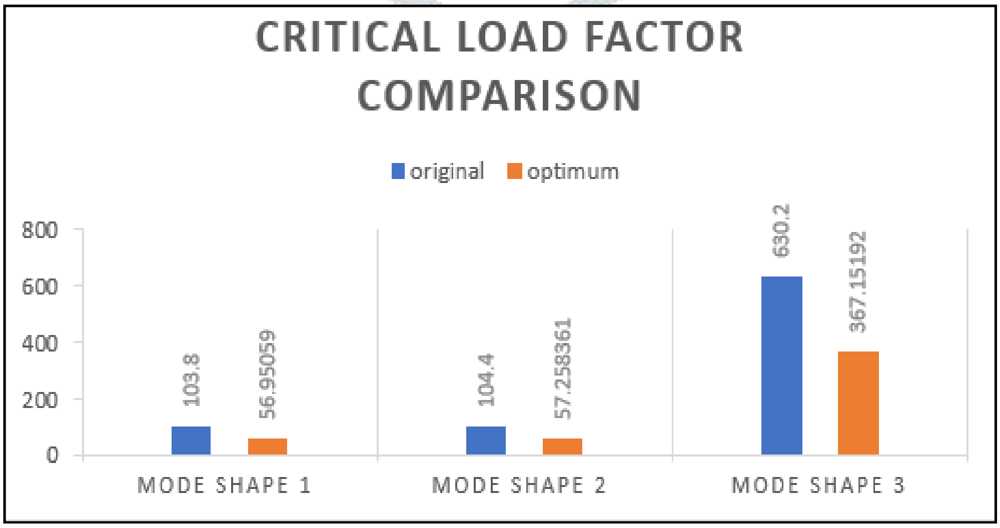

Chart -1: Critical load factor of actual and optimized circular section

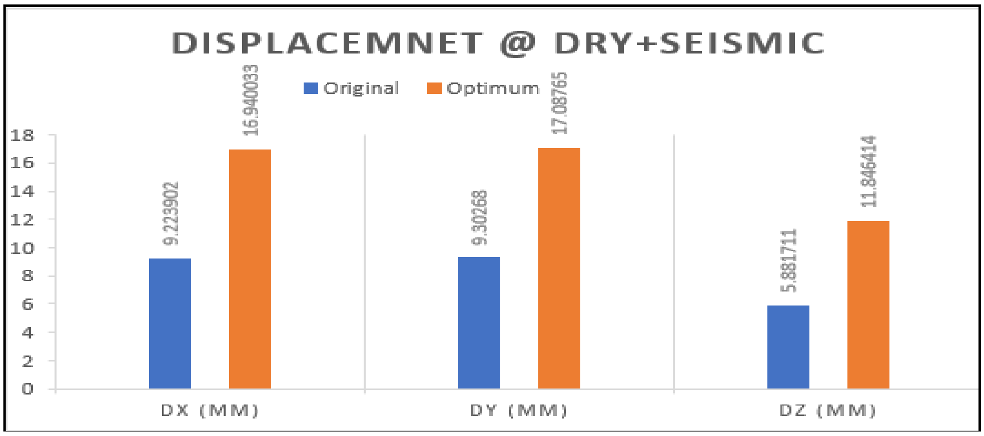

Chart 2: Displacement @ dry+seismic for actual and optimized circular section

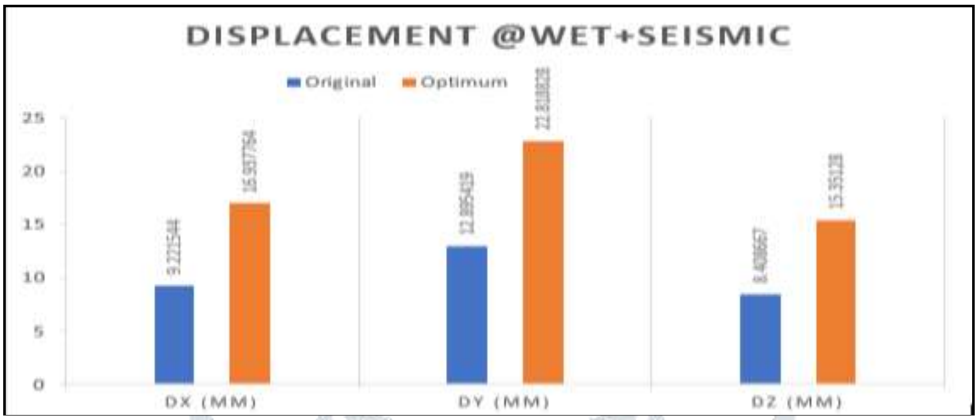

Chart 3: Displacement @ wet+seismic for actual and optimized circular section

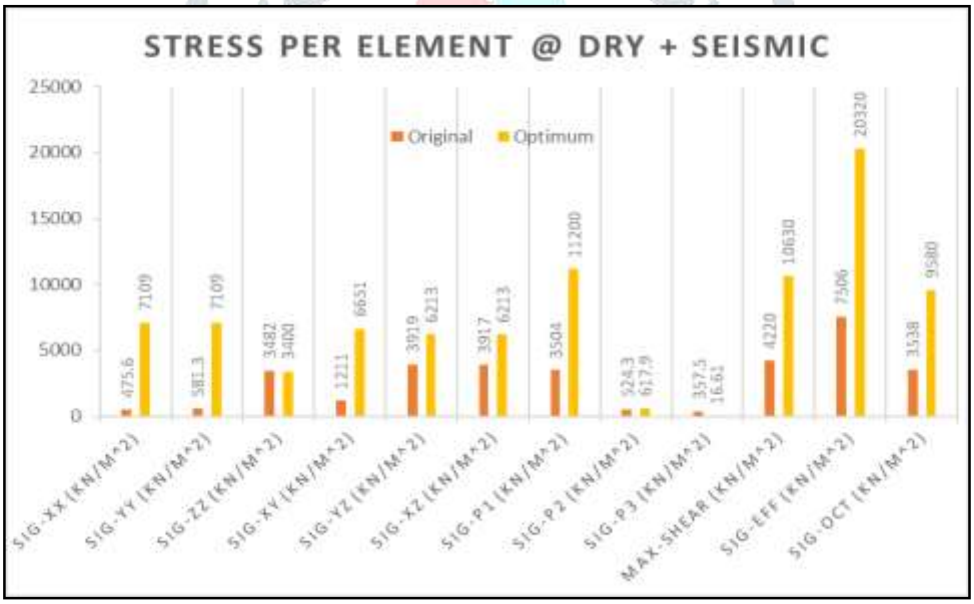

Chart 4: Stress @element for dry+seismic for actual and optimized circular section

- **Square section result**

Table -3: Percentage comparison of original and optimized square section

Variable	Square Section		% comparison
	Actual section	Optimized section	
Side dimensions	2.3 m	1.87	22.99%
Veticle load	13682 kN	13316 kN	2.75%
Load @ x- direction	1963.4 kN	1835.9 kN	6.94%
Load @ y- direction	1701.3 kN	1648.7 kN	3.19%
Moment @ x-direction	18942 kN/m^2	18044 kN/m^2	4.98%

Moment@ y- direction	16792 kN/m^2	16568 kN/m^2	1.35%
Area of concrete	5135800 mm^2	3408200 mm^2	50.69%
Gross-area	5290000 mm^2	3496900 mm^2	51.28%
Steel area	154170 mm^2	88690 mm^2	73.83%
Asc/meter	18138 mm^2	10434 mm^2	73.84%
Pt	2.9145	2.5363	14.91%
Min. bar provided	32 mm	28 mm	14.29%
Column bar provided	24	18	33.33%
Long. Bar spacing	95.8333 mm	103.8889 mm	-7.75%
Total long. steel weight	1532.2 kN	862.4 kN	77.67%
Trans. Bar provided	58	58	0.00%
Total Trans. steel weight	478.0231 kN	389.3476 kN	22.78%
Steel weight	2010.2 kN	1251.7 kN	60.60%
Steel cost	120610	75105	60.59%
Concrete cost	240100	159330	50.69%
Total cost	360710	234440	53.86%

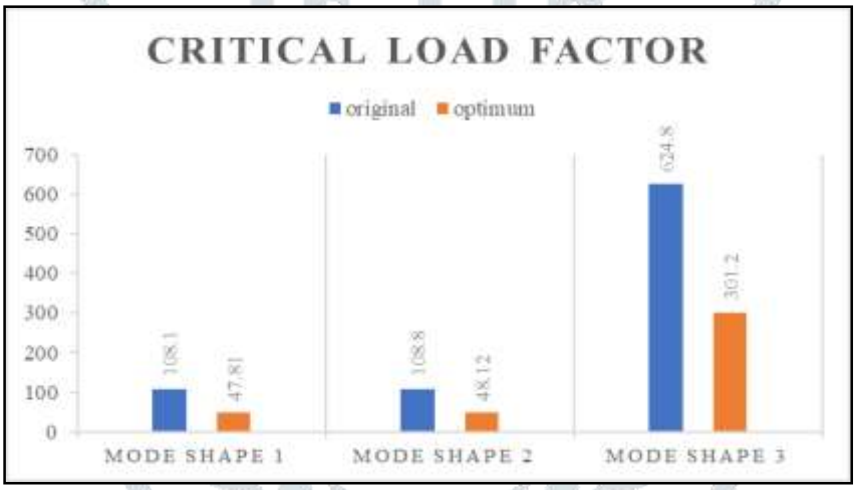

Chart 5: Critical load factor of actual and optimized square section

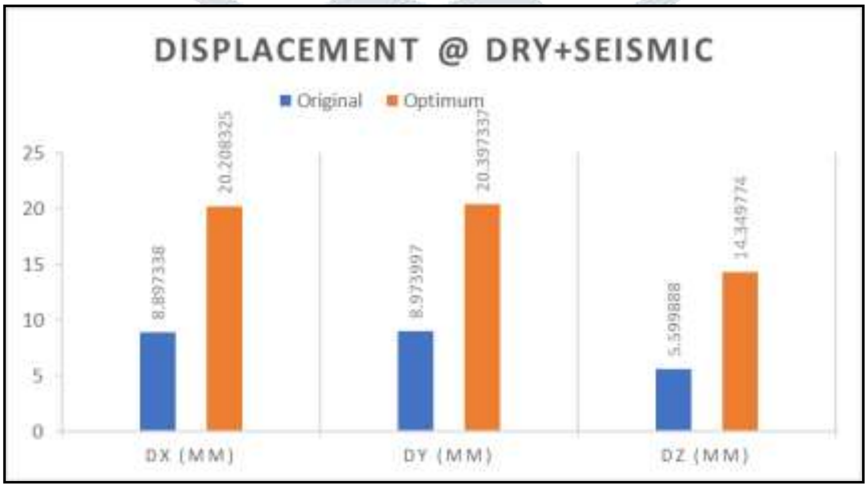

Chart 6: *Displacement @ dry+seismic for actual and optimized square section*

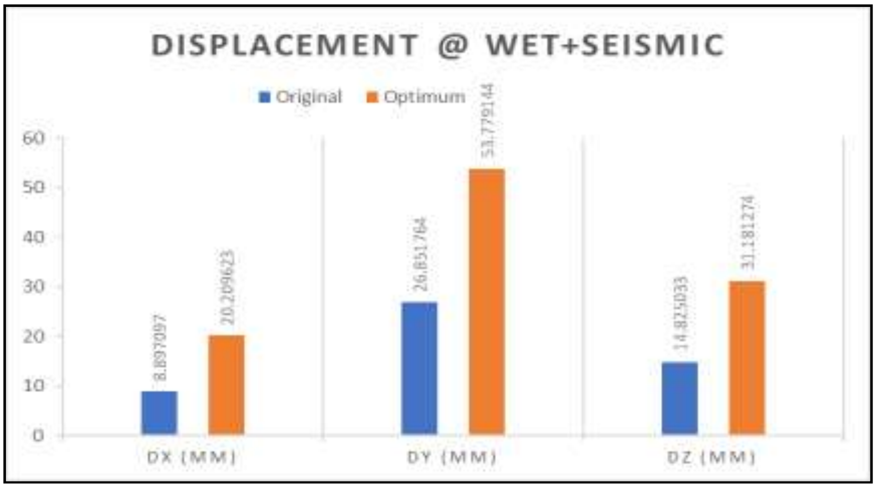

Chart 7: *Displacement @ wet+seismic for actual and optimized square section*

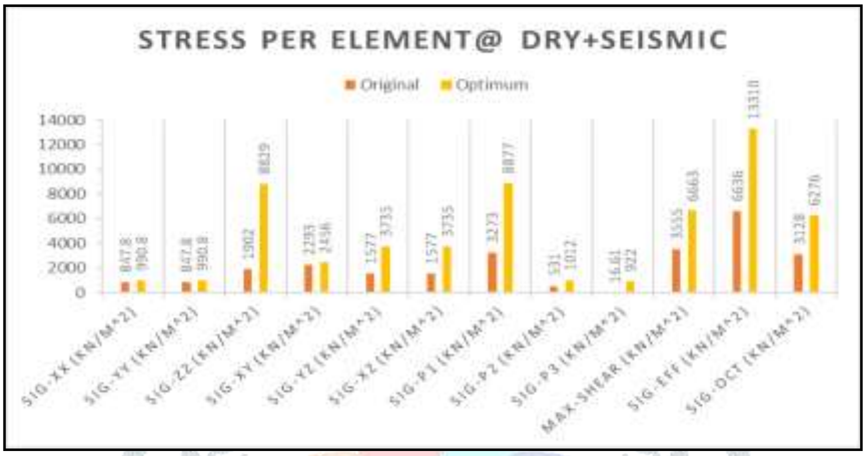

Chart 8: Stress @element for dry+seismic for actual and optimized square section

V. CONCLUSIONS

Optimizing any section required a large number of data and calculations for optimization but with the help of MATLAB, the procedure for finding the optimized section becomes a lot easier. With the help of MATLAB, size of the section, loads on section, steel required for section, cost of concrete, cost of steel, the weight of steel, no. of bars required are obtained.

- Total cost is reduced up to 38.41% and 52.39% for circular section and square section respectively.
- From buckling analysis, It was concluded that section obtains through optimization is safe from buckling although the critical load factor for buckling is less in optimized pier from which it has been decided that decrease in diameter increases the chances of buckling failure even though the obtained diameter is free from buckling.
- From the Displacement, it has been observed that the optimized section has attracted some amount of deformation as compared to the original shape
- The Square section has higher displacement as compared to the circular section.
- The square section attracts a large amount of water pressure has been observed by calculation and from displacement results also.
- The stress distribution on the effect of diameter variation indicates that if the diameter of the pier was decreased the contact surface also decreases and simultaneously stress pattern increased.
- The square edge is the worst for stresses and produces the highest rate of it as compared to Round corners which are better for stresses observed from the results.

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VII. REFERENCES

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