# *WEIGHT OPTIMIZATION OF PRE-ENGINEERED STEEL BUILDING BY GENETIC ALGORITHM.*

Rohith E[1],
*(M.E. Structural Engineering ,Civil Engineering Department, Sri Krishna College of Technology, Coimbatore)*
Dr. Sreevidya V[2]
*(Associate Professor, Civil Engineering Department, Sri Krishna College of Technology, Coimbatore)*
rohith.e@gmail.com

***Abstract : Typically, a pre-engineered building is a metal building that consists of light gauge metal standing seam roof panels on steel purlins spanning between rigid frames with light gauge metal wall cladding. It is a relatively flexible structure v/s a conventional steel framed building. In other words, it has a much greater vertical and horizontal deflection. During the last few years, several methods have been developed for the optimal design of steel structures. Most of the methods are calculus based nature and leads to unrealistic solutions and therefore, they are not used in practice, which still prefers to rely on the more traditional iterative methods. This paper describes the use of genetic algorithm (GA) in performing optimization of 2D truss structures to achieve minimum weight. The GA uses fixed length vector of the design variables which are the cross-sectional areas of the members. The objective considered here is minimizing the weight of the structure.***

***Keywords* – Pre-Engineered Buildings, Genetic Algorithm, Optimization.**

## I. INTRODUCTION

The use of steel framed structures for large industrial buildings permits the creation of buildings with large and uninterrupted span areas, with the advantage of low cost, light weight and easy installation. Portal frames have developed rapidly in recent years and are now widely applied to the construction of industrial factory buildings. The steel structures are required to be designed in such a way that they have enough strength and rigidity to satisfy the strength and serviceability limitation. But among them it is the most economical one that interests the structural engineer the most. Until the advent of structural optimization, the usual path to follow in the solution of this problem was to make use of the experience and intuition of the designer. The subject of optimization is a lively topic in almost every discipline. The unprecedented developments in computational capabilities in the last 40 years have fostered impressive developments in design optimization schemes in all discipline of engineering, so as in structural engineering. In the increased price of materials, the civil engineers and the manufacturers are forced to reduce the costs of construction and shorten the implementation period to maintain their competitiveness. As a result, a new design trend was born: the use of the analysis and design software to evaluate feasible design options, replacing the conventional design methods. The genetic algorithm (GA) optimisation approach is one such method and provides feasible results. In the increased price of materials, the civil engineers and the manufacturers are forced to reduce the costs of construction and shorten the implementation period to maintain their competitiveness. As a result, a new design trend was born.

## II. STRUCTURAL OPTIMISATION

The increasing interest in the area of optimisation for the last few decades is due to the availability of cheap and powerful computers, along with rapid developments in methods of structural analysis and optimization. Structures are becoming lighter, stronger, and cheaper as industry adopts higher forms of optimization. Weight optimization of structures plays a major role in many engineering fields. In some aspects it can be associated with cost optimization, since it obviously leads to an optimal material usage. the structure. It wasn't until the early 1950's that computer-based optimization launched itself into the engineering industry. This was due to the fact that the topic lends itself to numerical computation, which is the one task in which computers have superiority over humans. A recent addition to the family of numerical optimization

ISSN 2229-5518

methods is that of evolutionary computation. This category of optimization includes the genetic algorithm. The introduction of GAs into the field of structural optimization has opened new avenues for research because they have been successful where traditional methods have failed.

## III. METHODOLOGY

### GENETIC ALGORITHM.

These are nondeterministic stochastic search/optimization methods that utilize the theories of evolution and natural selection to solve a problem within a complex solution space. It derives its behavior from natural evolution and genetics, following Darwin's major principles of evolution. This method relies on random actions, trial and error, and survival of the fittest to evolve solutions to optimization. It acquires its strength from the fact that a wide variety of problems can be driven to very good solutions by recombining parts of previous good solutions. As engineers and designers search for new optimization methods, they find that the genetic algorithm can produce results never before possible.

### ROULETTE WHEEL SELECTION.

One way to implement this selection scheme is to imagine a roulette-wheel with its circumference marked for each string proportionate to the string's fitness. The roulette-wheel is spun n times, each time selecting an instance of the string chosen by the roulette-wheel pointer. Since the circumference of the wheel is marked according to a string's fitness, this roulette-wheel mechanism is expected to make $\frac{F_i}{\bar{F}}$ copies of the $i^{th}$ string in the mating pool. The average fitness $\bar{F}$ of the population is calculated as

$$\bar{F} = \sum_{i=1}^{n} F_i$$

Crossover and mutation are two basic operators of GA. Performance of GA depend on them. Type and implementation of operators depends on a problem. There are many ways how to do crossover and mutation. The considered crossover methods are Single point crossover operator is performed by randomly choosing a crossing site along the string and by exchanging all bits on the right side of the crossing site as shown in figure 1. In one site crossover, a crossover site is selected randomly (shown as vertical lines). The portion right of the selected site of these two strings is exchanged to form a new pair of strings. The new strings are thus a combination of the old strings.

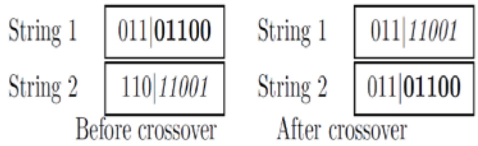


Fig-1. One site crossover operation.

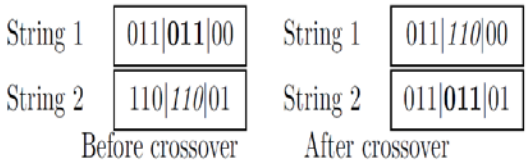


Fig-2. Two site crossover operation.

Two site crossover is a variation of the one site crossover, except that two crossover sites are chosen and the bits between the sites are exchanged as shown in figure 2. In one site crossover, a crossover site is selected randomly (shown as vertical lines). The portion right of the selected site of these two strings is exchanged to form a new pair of strings. The new strings are thus a combination of the old strings.

### MUTATION.

This operator occurs much less frequently both in nature and GA. The basic idea of using this operator is to introduce some diversity into the population. In other words, to delay the situation in which all the population becomes so homogeneous that no further improvement is possible. In the creation of new solution, there is always a small probability for each bit in the string to change from 0 to 1 or vice versa. If so, the solution is *mutated*. The probability of mutation $P_m$ is 0.01

00 → 001000000000

### GA TERMINOLOGY

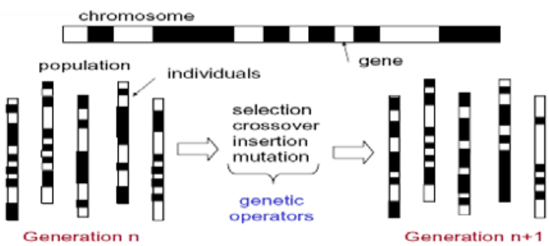


Fig-3. GA Terminology

ISSN 2229-5518

Binary Encoding uses 0's and 1's in a chromosome
Each bit corresponds to a gene
The values for a given gene are alleles

Individual - Any possible solution.
Population - Group of all individuals
Search Space - All possible solutions to the problem
Chromosome - Blueprint for an individual
Individual - Any possible solution.
Population - Group of all individuals
Search Space - All possible solutions to the problem
Chromosome - Blueprint for an individual
Trait - Possible aspect of an individual
Locus - The position of a gene on the chromosome
Trait - Possible aspect of an individual
Locus - The position of a gene on the chromosome
Genome - Collection of all chromosomes for an individual
Selection - Individuals chosen for later breeding.
Crossover- Selecting genes from parent chromosomes and creating new off springs.
Mutation- Randomly changes the resulting offspring from crossover.

STRUCTURE

The structure to be optimized in this project is a pre-engineered building. The considered structure is a storage building of ITI. Ltd. It is located in Palakkad district in Kerala.

The considered portal frame structures are optimized under the combined effects of the self-weight of frame members, vertical uniformly distributed surface variable load and horizontal surface variable load (wind). The purlins as well as rails and secondary facade columns are designed to transfer permanent load (self-weight and weight of panels) and variable load to the frame structure. When the ultimate limit state of structural members is considered, the elements are checked for axial resistance, shear resistance, bending moment resistance and displacement. The structure .considered consists of equal main portal frames, mutually connected with equal purlins. Each portal frame is constructed from four columns and two beams. The structure consists of 17 frames. Each bay is made up of built up sections as shown in figure 5. Purlins run continuously over the portal frames. Columns, beams and purlins are composed of built-up sections.

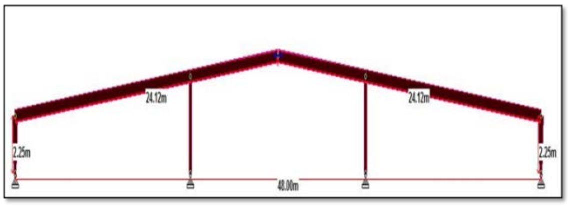

Fig- 4. The Structure.

## IV. ANALYTICAL INVESTIGATION

OPTIMISATION TECHNIQUE.

For the ease of analysis using genetic algorithm the frame is assumed to be composed of 4 sections. This structure is known as the equivalent or resonant structure. This resonant structure thus produces 6 values or 6 areas. It is given in the table below. These values are the input to the genetic algorithm.

TABLE 1 INITIAL QUANTITY TO BE OPTIMISED.

| | PLATE NO. | AREA $M^2$ | THICKNESS $M$ | VOLUME $M^3$ | WEIGHT $KG$ |
|---|---|---|---|---|---|
| COLUMN | 1 | 0.452 | 0.006 | 0.002 | 15.7 |
| COLUMN | 2 | 0.453 | 0.006 | 0.0027 | 15.9 |
| COLUMN | 3 | 0.824 | 0.006 | 0.0094 | 38.8 |
| COLUMN | TOTAL | | = | | 70.4 |
| | PLATE NO. | AREA $M^2$ | THICKNESS $M$ | VOLUME $M^3$ | WEIGHT $KG$ |
| RAFTER | 1 | 4.43 | 0.006 | 0.026 | 204.1 |
| RAFTER | 2 | 4.43 | 0.006 | 0.026 | 204.1 |
| RAFTER | 3 | 12.13 | 0.006 | 0.072 | 565 |
| RAFTER | TOTAL | | = | | 973 |

The software used for the optimization process is MATLAB. The GA program is created as per the requirements and it includes the various genetic program then produces optimized results as shown below. The fitness function considered for optimization is

$$f(A)=\Sigma \rho A L$$

Where,

$\rho$= material density

L =length of the member

A = Area of the sections

Here the material density and length of the member is constant and the only variable is the area and it is optimized using the GA technique. In the considered structure the optimization is achieved by minimizing the weight of the structure.

STAAD PRO. ANALYSIS.

The genetic algorithm program creates new values or section areas. From these obtained values a frame is created in Staad Pro and it is analyzed for various loads. Loads considered are dead load, live load and wind load. Various wind load combinations are considered to ensure whether the structure is safe or not. Loads are then applied according to IS 800 and IS 875. The resulting frame is checked for deflection criteria. Only when the Staad Pro results are safe, the optimization procedure is a success.

TABLE 2 OPTIMISED QUANTITY

| | PLATE NO. | AREA $M^2$ | THICKNESS *M* | VOLUME $M^3$ | WEIGHT *KG* |
|---|---|---|---|---|---|
| COLUMN | 1 | 0.313 | 0.006 | 0.00188 | 15.53 |
| | 2 | 0.316 | 0.006 | 0.0019 | 15.72 |
| | 3 | 0.77 | 0.006 | 0.00464 | 36.88 |
| | TOTAL | | = | | 68.137 |
| RAFTER | **PLATE NO.** | **AREA $M^2$** | **THICKNESS *M*** | **VOLUME $M^3$** | **WEIGHT *KG*** |
| | 1 | 3.83 | 0.006 | 0.022 | 196.9 |
| | 2 | 3.83 | 0.006 | 0.022 | 196.9 |
| | 3 | 10.58 | 0.006 | 0.0635 | 541.27 |
| | TOTAL | | = | | 935.07 |



## V. Result and Discussion.

TABLE 3 COMPARISON OF INPUT AND OPTIMISED QUANTITY.

| | PLATE NO. | INITIAL WEIGHT | OPTIMIZED WEIGHT | % REDUCTION |
|---|---|---|---|---|
| COLUMN | 1 | 15.7 | 15.53 | 1.08 % |
| | 2 | 15.9 | 15.72 | 1.13 % |
| | 3 | 38.8 | 36.88 | 4.94 % |
| RAFTER | **PLATE NO.** | **INITIAL WEIGHT** | **OPTIMIZED WEIGHT** | **% REDUCTION** |
| | 1 | 204.1 | 196.9 | 3.52 % |
| | 2 | 204.1 | 196.9 | 3.52 % |
| | 3 | 565 | 541.27 | 4.20 |

Weight of the frame considered is 1044 kg. Weight of optimized frame is 1004 kg. There is optimization or reduction of 40kg.So the genetic algorithm can optimize weight up to 4% .As the weight optimization is directly linked to cost optimization, considerable savings can be obtained by the application of GA. The entire structure consists of 17 bays. So in total an optimization of 680 kg can be achieved.

STABILITY CHECK.

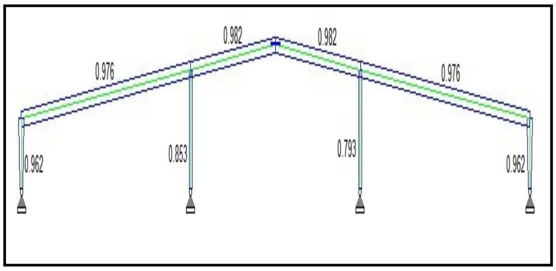


Fig- 5. Utilisation ratio of optimized frame.

## VI. Conclusion.

Using the GA programs to optimize the portal frame design has many advantages, such as precise calculation, fast convergence, convenience and reliability. Under the conditions of the various constraints in codes, optimal results can be obtained to give reduction of materials. From the GA based optimization result, the weight and cost of pre-engineered building frame is saved by approximately.

## Acknowledgements

I wish to express my sincere thanks to “Sri Krishna College of Technology, Coimbatore and Staffs of Civil Engineering Department” for providing all the facilities for carrying out this work and for encourage me in completing the project and for their valuable guidance and timely suggestions during the project work.

I wish to thank my guide Dr.Sreevidya Ph.D for her support throughout the project.Finally

I wish to thank my parents and my classmates for their general support.

## References

1. Goldberg D E, “Genetic algorithm in search, optimization and machine learning.” New York, Addison-Wesley publications.1989
2. Rajeev and Krishnamoorthy .”Genetic Algorithms – Based Methodologies for Design Optimisation of Trusses.” ASCE Journal of Structural Engineering, 123 (3), pp 350-358.1997.

ISSN 2229-5518


3. Kalyanmoy Deb and Surendra Gulati "Design of truss-structures for minimum weight using genetic algorithms", Finite elements in analysis and design. Vol. 37, pp 447-465.2007.
4. C. Vasanthakumar" Structural optimization of an industrial building frame by genetic algorithm" International Journal of Engineering Science and Technology Vol. 5 No. 06S.2013
5. Rajesh Kumar , "Cost Optimization of Industrial Building using Genetic Algorithm" International Journal of Scientific Engineering and Technology,Volume 2, Issue 4, pp 185-191.2013