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Optimization of Industrial Structure using Light Gauge Steel Section

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Abstract - *In recent decades the interest of the building sector is tending towards the lightweight construction so as to overcome the faults of the last decades. The light weight and faster construction is the demand of the era. This has led to the increase in the use of the light weight steel structure as they satisfy the demand of the light weight and faster construction. Though there are several advantages of the light gauge steel section they are partially obtained due to the unawareness of the designer about the behaviour of the section. Therefore it is necessary to study the behaviour of the light gauge section under loading which will help in achieving the good performance of the structure.*

Key Words: Steel chimney, industrialization, Stacks, IS 875, IS 6533, Optimal design

1. INTRODUCTION

The design of industrial building is governed mainly by functional requirements and the need for economy of construction. In cross-sections these buildings will range from single or multiday structures of larger span when intended for use as warehouses or aircraft hangers to smaller span buildings as required for factories, assembly plants, maintenance facilities, packing plants etc. The main dimensions will nearly always be dictated by the particular operational activities involved, but the structural designer's input on optimum spans and the selection of suitable cross-sections profile can have an important bearing on achieving overall economy. An aspect where the structural designer can make a more direct contribution is in lengthwise dimensions i.e. the bay lengths of the building. Here a balance must be struck between larger bays involving fewer, heavier main components such as columns, trusses, purlins, crane beams, etc. and smaller bays with a large number of these items at lower unit mass. An important consideration in this regard is the cost of foundations, since a reduction in number of columns will always result in lower foundation costs.

Structural engineers and designers are in the daily engineering praxis required to design the cheapest possible structures with the minimum amount of used material and technical equipment. The use of modern optimization methods thus becomes a great opportunity in the area of structural engineering. Single-storey industrial steel building structures are probably the most frequently built type of structures among various skeletal framed steel constructions. Many different optimization approaches have been proposed in the near past for the optimization of these structures. Performed a constrained non-linear cost optimization of steel portal framed building. A linear programming approach for the optimal design of pitched roof frames. Considered an optimum design of pitched roof steel frames with hunched rafters by using a genetic algorithm and using light gauge section in the structure.

1.1 Failure Modes In Light Gauge Steel Section

a. Local buckling

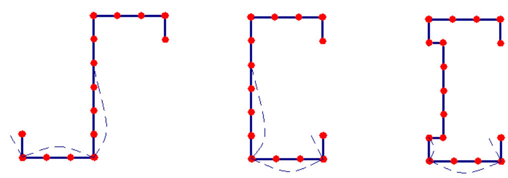

Fig -1: Local Buckling

Local buckling is characterised by ripples of relatively short half-wavelength of the order of magnitude of individual plate elements and the displacements are only perpendicular to plate elements while the fold lines remain straight.

b. Distortional Buckling

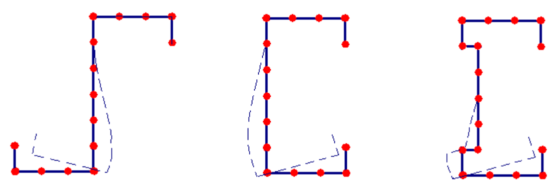

Fig -2: Distortional buckling

Distortional buckling occurs only in the structural members of open cross-sections. This buckling is characterized by the distortion of the cross-section of the structural member.

c. Lateral Torsional Buckling

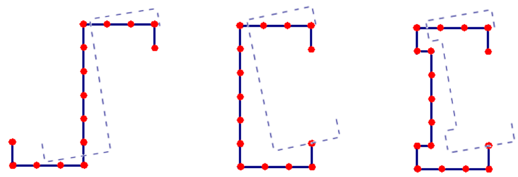

Fig -3: Lateral Torsional buckling

The buckling of a strut in compression or a beam in bending is called Euler buckling or lateral-torsional buckling; Lateral-torsional buckling usually occurs when a rigid body is bent to twist and translates to have lateral movements but do not have deformation in shape of cross-section.

2. LITERATURE SURVEY

2.1Mr. Roshan S Satpute, Dr. Valsson Varghese, (2012)

Cold formed steel section are extensively used in industrial and many other non-Industrial constructions worldwide, it is relatively a new concept in India. These concepts were introduced to the Indian market lately in the 1990's with the opening up o f the Indian economy and a number of multi-nationals setting up their green-field projects. Global Cold formed steel have established their presence in India by local marketing agents and certified builders. As the complete building package is supplied by a single vendor, compatibility of all the building components and accessories is assured. This is one of the major benefits of the Cold formed building system. When a building is no longer needed it can be disassembled, stored or moved to another location and re-erected because only bolted connections are used. There is no field riveting or welding & the rigid frame is strong. By using Cold formed system economy is achieved with completion of project in minimized time. In this project the detailed analysis of Industrial building with Cold formed concept is carried out. The Work is also extended by taking the parametric studies too. A comparative study has also been carried out between Hot Roll steel Industrial building and Cold formed Industrial building and a conclusion has been drawn.

2.2 Babar Hussain and Dr Ajay Swarup, (2017)

Integrated structural analysis and design software packages, which generally work on finite element method for analysis and design, have been gaining popularity in the field of designing since they have reduced the tedious calculation process to a simple process of just giving input values. The result generated is according to the values entered without the consideration of the feasibility. Moreover, optimization of structures has been a lesser used concept in day-to-day working and is independent of design and analysis of the structures. This paper provides a study of various levels of research work done in computational structural analysis. The crust of our review focuses on the analysis of optimization of truss, complex or simple because truss is the most widely used and fundamental building block of any structure.

2.3 Perampalam Gatheeshgar, Keerthan Poologanathan, Shanmuganathan Gunalan and et.al,(2019)

Cold-formed steel (CFS) members have been significantly employed in light gauge steel buildings due to their inherent advantages. Optimizing these CFS members in order to gain enhanced load bearing capacity will result in economical and efficient building solutions. This research presents the investigation on the optimisation of CFS members subjected to flexural capacity and results. The optimization procedure was performed using Particle Swarm Optimization (PSO) method while the section moment capacity was determined based on the effective width method adopted in EN1993-1-3 (EC3). Theoretical and manufacturing constraints were incorporated while optimizing the CFS cross-sections. In total, four CFS sections (Lipped Channel Beam (LCB), Optimised LCB, Folded-Flange and Super-Sigma) were considered including novel sections in the optimization process. The section moment capacities of these sections were also obtained through non-linear Finite Element (FE) analysis and compared with the EC3 based optimised section moment capacities. Results show that compared to the commercially available LCB with the same amount of material, the novel CFS sections possesses the highest section moment capacity enhancements up to 65%. In addition, the performance of these CFS sections subject to shear and web crippling actions were also investigated using nonlinear FE analysis.

2.4 S. Kravanja and T. Zula, (2010)

The paper presents the simultaneous cost, topology and standard cross-section optimization of single storey industrial steel building structures. The considered structures are consisted from main portal frames, which are mutually connected with purlins. The optimization is performed by the mixed-integer non-linear programming approach, MINLP. The MINLP superstructure of different structure/topology and standard cross-section alternatives has been generated and the MINLP optimization model of the structure has been developed. The defined cost objective function is subjected to the set of (in)equality constraints known from the structural analysis. Internal forces and deflections are calculated by the elastic first-order analysis constraints. The dimensioning constraints of steel members are defined in accordance with Eurocode 3. The modified outer-approximation/equality-relaxation (OA/ER) algorithm, a two-phase MINLP strategy and a special pre-screening procedure of discrete alternatives are used for the optimization. A numerical example of the cost optimization of a single-storey industrial steel building is presented at the end of the paper.

2.5 Niraj P. Kareliya and Kaushik C. Koradia, (2016)

This in this paper, Genetic Algorithm based optimization presents for the design of portal frame according to Indian standard code. The design mainly consists of column element, Rafter element and hunched portion design. Pre engineering building have light gauge metal steel purlin,matel clading,and economic sections of column, rafter and haunched portion. In this project MAT-LAB

Genetic Algorithm has been used to find the optimum design of portal frame according to "IS Code". This design aid can be used directly on structural design practice.

3. METHODOLOGY

Lightweight steel framed structural elements in buildings construction provided a way of raising building sustainability. These structural elements have several advantages, such as presenting a great potential for recycling and reuse, allowing the conservation of natural resources and the environment. The high thermal conductivity of steel could be a drawback, leading to thermal bridges if not well designed and executed. The LSF construction system is described and analysed in order to show its main advantages and drawbacks. The assessment of embodied and operational energy is essential to perform a life cycle analysis. The reduction of both energies consumption is crucial to increase the sustainability performance. Special focus is given to describe and exemplify several strategies for improvement of thermal performance and energy efficiency of light gauge steel section.

3.1 Light Gauge Steel Section

Light gauge steel structures are steel structural products that are made by bending flat sheets of steel at ambient temperature into shapes which will support more than the flat sheets themselves. They have been produced for more than a century since the first flat sheets of steel were produced by the steel mills. However, in recent years, higher strength materials and a wider range of structural applications have caused a significant growth in light gauge steel relative to the traditional heavier hot-rolled steel structural members. Light gauge steel members have been widely used in building applications as the secondary cladding and purlin applications as well as the primary applications as beams and columns of industrial and housing systems. Consumption rate of light gauge steel products is growing steadily.

3.2 Design of the Channel Section as Per Is 801-1975

Computation as per IS: 801-1975 of practice for use of cold formed light gauge steel structural member's in general building construction:

Material Properties: yield stress fy = 250 N/mm2

Computation of Sectional Properties:

Depth (d) = 100 mm

Width (w) = 40 mm

Depth of lip (D) = 20 mm

Thickness (t) = 2 mm

Area (A) = 424 mm2

Span of length (L) = 1000 mm

Centroid: CG of section: Xcg = 14.623 mm

Zcg = 37.103 mm

Moment of inertia: Ixx = $\frac{40X2^3}{12} + 40X2X49^2 + \frac{2X18^3}{12} + 18X2X40^2 + \frac{2X96^3}{12} + \frac{40X2^3}{12} + 40X2X49^2 + \frac{2X18^3}{12} + 18X2X49^2 = 0.649$ X 106 mm4

Izz = $\frac{2X40^3}{12} + 40X2X5.377^2 + \frac{2X40^3}{12} + 40X2X5.377^2 + \frac{18X2^3}{12} + 18X2X24.377^2 + \frac{96X2^3}{12} + \frac{18X2^3}{12} + 18X2X24.377^2 =$ 0.068832 X 106 mm4

Computation of effective width:

Checking of above section as per clause 5.2.2.1 IS 801-1975 (Page No: 6):

Effective width calculation of compression elements:

Flange is fully effective

if $\left(\frac{w}{t}\right) \leq \left(\frac{w}{t}\right)_{lim}$

Hence $\left(\frac{w}{t}\right) = \left(\frac{40}{.2}\right) = 20$

$\left(\frac{w}{t}\right)_{lim} = \frac{1435}{\sqrt{f_y}} = \frac{1435}{\sqrt{225}} = 95.667$

Hence $\left(\frac{w}{t}\right) < \left(\frac{w}{t}\right)_{lim}$

Therefore Entire area is effective.

Determination of safe load:

Section modulus Ze = $\frac{I_{xx}}{Z_{cg}} = \frac{.648812 \text{ X } 10^6}{37.103}$ = 17530.721 mm3

Allowable resisting moment = Ze X fy

= 225 X 12976.44

M = 2.912 x 106 Nmm

Let w be the load in N/mm

$\frac{w \text{ X } 1000^2}{8} = 2.912\ X\ 106$ N/mm

w = 23.296 N/mm

Check for web shear :

Maximum Shear force = V = $\frac{23.296 \text{ X } 1000}{2}$

= 11.648 X 103 N

Maximum average shear stress Fmax = $\frac{V}{A}$

= $\frac{11.648 \text{ X} 10^3}{424}$

=27.472 N/mm2

$\frac{h}{t} = \frac{100}{2}$

= 50

$4590/\sqrt{f_y} = 4590/\sqrt{225}$

= 306

As per clause 6.4.1 IS 801-1975 (Page No: 15)

Since $\frac{h}{t} < 4590\sqrt{f_y}$

Therefore the gross area of a flat web = Fv

$= \frac{1275\sqrt{f_y}}{\frac{h}{t}}$

$= \frac{1275\sqrt{225}}{50}$

Fv = 382.50 N/mm2

Fv must not be greater than Fvmax = 0.4fy

= 0.4 X 382.50

Fvmax = 90 N/mm2

Hence Fv = Fvmax =90 N/mm2.

Thus, Fv = Fvmax = 90 N/mm2 this is greater than the maximum Average shear stress of Fmax = 27.472 N/mm2. Thus the beam is therefore safe in shear.

Check for bending compression in web :

As per clause 6.4.2 IS 801-1975 (Page No: 16):

Actual compression stress at junction of flange and web:

fbw = fc X $\frac{40-2}{40}$

= 0.4 X 225 X $\frac{40-2}{40}$

= 85.5 N/mm2

Permissible: Fbw = $\frac{36560000}{\left(\frac{h}{t}\right)^2}$ kg/cm2

$= \frac{3585311.24}{(50)^2}$ N/mm2

= 1433.152 N/mm2

Since Fbw > fbw. Hence safe in bending.

Combined Bending and Shear Stresses in Webs :

As per clause 6.4.2.3 IS 801-1975 (Page No: 16):

$$\sqrt{\left(\frac{f_{bw}}{F_{bw}}\right)^2 + \left(\frac{F_{max}}{F_v}\right)^2} \leq 1$$

Where, fbw= actual compression stress at junction of flange and web;

Fmax = actual average shear stress, that is, shear force per web divided bv webs area;

Fv = allowable shear stress, except that the limit of 0.4fy, shall not apply.

$$\sqrt{\left(\frac{85.5}{1433.152}\right)^2 + \left(\frac{27.472}{90}\right)^2} = .311$$

Since Combined Bending and Shear Stresses in Webs is less than unity.

Hence the section is safe.

Determination of deflection:

Deflection $\delta = \frac{5wL^4}{384EI} < \frac{L}{325}$

Where w = 150.4 kN/m = 150.4X103 N/mm

L = 1000 mm

E = 2.033 X 105 N/mm2

Ixx = 505.1343 X 104 mm4

Hence $(\delta) = \frac{5X\ 23.296\ X\ (950)^4}{384\ X\ 2.033\ X\ 10^5 X\ 648.812X\ 10^3}$

= 2.338 mm.

Permissible:

$\frac{L}{325} = \frac{950}{325}$ = 3.076 mm. Hence safe.

4. CONCLUSIONS

The optimization of industrial structure by maximum using light gauge steel sections in whole structure. In addition, the performance of the innovative optimised sections subject to shear and web crippling action were also investigated using analysis. The various advantages and disadvantages of light gauge steel section for the industrial structure, lightweight steel framed structural elements in construction provided a way of raising building sustainability. Following points are observed that in this study for optimization of industrial structure

i. They are light, and allow quick structure without heavy tools or equipment. Every component can easily be carried by hand a carpentry job on a larger scale.
ii. It is able to shape itself to any form, and can be clad and insulated with a wide range of materials.
iii. It is easy to change or modify this construction at any point in its lifespan.
iv. There are a great range of systems and products catering to this type of construction.

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