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Review of Optimizing 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 behavior of the section. Therefore it is necessary to study the behavior of the light gauge section under loading which will help in achieving the good performance of the structure 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 determination result in economical and efficient building solutions. This research presents the investigation on the optimization of CFS members subjected to flexural capacity and results.*

1. *INTRODUCTION*

A large steel structures being built are only single storey buildings for industrial purpose. Secondary structural members span the distance between the primary building frames of metal building systems. They play a complex role that extends beyond supporting roof and wall covering and carrying exterior loads to main frames. Secondary structural's, as these members are sometimes called, may serve as flange bracing for primary framing and may function as a part of the building's lateral load–resisting system. Roof secondary members, known as purlins, often form an essential part of horizontal roof diaphragms; wall secondary members, known as girts, are frequently found in wall bracing assemblies. The majority of steel structures being built are only low-rise buildings, which are generally of one storey only. Industrial buildings, a sub-set of low-rise buildings are normally used for steel plants, automobile industries, light, utility and process industries, thermal power stations, warehouses, assembly plants, storage, garages, small scale industries, etc. These buildings require large column free areas. Hence interior columns, walls and partitions are often eliminated or kept to a minimum.

2. *LITERATURE REVIEW*

1. **Shigeaki Tohnai, Hiroyuki Kaibara,Tomohisa Hirakawa And Et.Al, " Transition of Light-Gauge Steel Framed Houses And development Of Four-Story Steel-Structured Housing Method"**

In November 2001, light-gauge steel framed houses were legislated under a Building Standard Law in Japan as a new structural system. In September 2012, the notification was revised. Then, as for the light-gauge steel framed houses, limit of the number of stories is relaxed, blended structure with other structure is enabled, and design flexibility is extended. With notification revision, we had developed the original steel-structured housing system, realized 3- storied and 4 storied houses at last, by developing high strength bearing wall and joining hardware, improving fireproof performance of membrane.

2. **Mr. Roshan S Satpute, Dr. Valsson Varghese,(2012) "Building Design Using Cold Formed Steel Section"**

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

3. **Babar Hussain and Dr Ajay Swarup, (2017) " A Review On Steel Structural Analysis For Optimization Of Trusses"**

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.

4. **Perampalam Gatheeshgar, Keerthan Poologanathan, Shanmuganathan Gunalan and et.al , (2019) " Structural behaviour of optimised cold formed steel beams"**

Cold-formed steel (CFS) members have been significantly employed in light gauge steel buildings due to their inherent advantages. Optimising 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 optimisation procedure was performed using Particle Swarm Optimisation (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 optimising 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 optimisation 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.

5. **S. Kravanja and T. Zula, (2010) "Cost optimization of industrial steel building structures"**

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.

6. **Niraj P. Kareliya and Kaushik C. Koradia, (2016) " Steel optimization in Industrial Building using Pre-Engineering Building"**

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 has light gauge metal steel purlin, matel cladding 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.

7. **W. Leonardo Cortés-Puentes, Dan Palermob, AlaaA bdulridha and Muslim Majeed, (2016) " Compressive strength capacity of light gauge steel composite columns"**

The axial compressive strength capacity of concrete-filled light gauge steel composite columns was assessed through an experimental program involving twelve long and fourteen stub columns with width-to-thickness ratio of 125 for the encasing steel section. A comparison between concrete-only and confined stub columns demonstrated that the stub column experiences an increase of strength of up to 16% duet confinement. The compressive strength contribution of the light gauge steel section was limited by local buckling. Specifically, the steel-only stub column section slacking the concrete core experienced, on average, approximately 33% of its full compressive strength. The full-scale composite column sill strutted at the axial compressive strength capacity was controlled by end bearing capacity and local buckling of the light gauge steel.

8. **G. T. Taylor, M. Macdonald and J. Rhodes, (1998) " The Design Analysis of Light Structures with Combined Aluminium/Steel Sections"**

Extruded aluminium hollow box sections with steel section inserts are riveted together to form a combined member increasingly used as the basis for the production of skeletal structures ranging from shelters on transport routes to larger covered walkways at airports, hospitals and industrial compounds. At these locations the structures have to be functional, safe and attractive. The paper reports on research work carried out on the stress and deflection behaviour of a typical riveted combined member investigated using the finite element method and supported by experimentation. The effect of the fit between the steel section and the aluminium section is given particular attention. The paper goes on to report the results of an examination of the dynamic response of light aluminium/steel structures, where the dynamic analysis is carried out using the finite element method and long walkway shelters, upwards of 300 m, are a particular focus. The results of a parametric study are presented and combined with wind excitation criteria design curves are proposed. Conclusions are drawn on the engineering value of the use of aluminium/steel combined members including the implications for the design of light aluminium/steel structure.

9. **Jeffrey W. Bermana, Oguz C. Celik and Michel Bruneau, (2015)" Comparing hysteretic behavior of light-gauge steel plate shear walls and braced frames"**

Braced frames and steel plate shear walls (SPSWs) have both been shown to be useful in the seismic retrofit of buildings. While both these systems have merit, no guidance exists to help the engineer determine which of the two approaches is preferable in terms of providing stiffness, maximum displacement ductility, cumulative hysteretic energy dissipation, and energy dissipation per cycle for a given strength. In an attempt to provide some quantitative data and insight for this purpose, this paper describes and compares the results from cyclic testing of six frames: four concentrically braced frames (two with cold-formed steel studs for in-plane and out-of-plane restraint of the braces and two without), and two light-gauge steel plate shear walls (one with a flat infill plate and one with a corrugated infill). The largest initial stiffness was provided by a braced frame specimen with cold formed steel studs and the largest ductility was achieved with a steel plate shear wall with flat infill. After scaling the hysteretic results to the same design base shear, it was found that both the energy dissipated per cycle and the cumulative energy dissipation were similar for flat plate SPSW and braced frames with two tubular braces, up to a ductility of four. After that the tubular braces fractured while the SPSW with a flat infill reached a ductility of nine before the energy dissipation per cycle decreased.

10. **Christian Haase, Christoffer Zehnder, et.al, (2017) " On the deformation behavior of k-carbide-free and k-carbide containing high-Mn light-weight steel" Acta Materialia, Vol. No - 122, Pp.No 332- 343, 2017.**

Light-weight high-manganese steels offer a high potential for industrial application due to their excellent combination of mechanical properties and reduced density. In the present work, the deformation behavior of an Fe-29.8Mn-7.65Al-1.11C steel was investigated by means of TEM microstructure analysis and XRD texture measurements. CALPHAD calculations were used to determine the processing parameters for the applied heat treatments in order to produce essentially different initial microstructures, i.e. single-phase austenite in homogenized condition with large grain size (state A), 2-phase steel composed of austenite and k-carbides in aged condition with large grain size (state B), and single-phase austenite in recrystallized condition with fine grain size (state C). Since this is the first study to directly compare the plastic deformation of the same alloy with and without k-carbides, the influence of the precipitation state could be successfully identified. Although the mechanical properties were strongly affected by grain size and precipitation state, the developed deformation microstructures and textures appeared very similar and evidenced the activation of the same deformation mechanisms in the material in states A, B, and C. The strong work hardening in these alloys was facilitated by planar dislocation glide leading to slip band refinement, i.e. Slip band Refinement-Induced Plasticity (SRIP) rather than micro band formation. The reasons for this deformation behavior as well as its influence on the evolution of rolling and tensile textures are discussed.

11. **Mansour Momenia, Farhad Golestani-Fard, (2015)" Development of visible light activated TiO2 thin films on stainless steel via sol spraying with emphasis on microstructural evolution and photocatalytic activity"**

Visible light activated nitrogen doped TiO_2 thin films were developed on 304 stainless steel by sol spraying method using a common painting airbrush. Thin films with different thickness were prepared and calcined at various temperatures from 400 to 600°C. The samples were studied using ellipsometry, XRD, GIXRD, XPS, DRS, SEM and FESEM. Photocatalytic activities of the films were investigated by measuring their ability to degrade ethylene blue solution under visible light irradiation. Results revealed that uniform nanostructured films with a thickness range of 29-150 nm were successfully prepared on stainless steel by sol spraying. Doping nitrogen into TiO_2 structure restricted the crystallite growth of anatase phase and reduced the band gap energy to 2.85 eV and therefore, activated TiO_2 in visible light region. Increasing calcination temperature not only promoted crack formation in thin films, but also encouraged Fe diffusion from substrate into thin films structure. However, the N doped TiO_2 film calcined at 500°C with a thickness of 150 nm indicated a significant photocatalytic activity in visible light with 22% higher efficiency in comparison with undoped TiO_2 film. Development of TiO_2 based photo catalytic thin films by a simple method of airbrushing, builds up the hope for industrial scale applications in future.

12. **H. Burstrand, (1998) " Light-gauge Steel Framing Leads the Way to an Increased Productivity for Residential Housing "**

In a short period of time, the Swedish building industry has shown how to make the construction process more efficient by using light-gauge steel framing for housing. The construction industry in Sweden has been characterised by low productivity, stiff regulations from the government and adhering to old traditions. During the last five years, the building market has been very low. At the same time the rather extensive governmental subsidies were phased out. We have to develop a new construction process for residential housing to make houses affordable for people. The question how to reduce building costs has been frequently discussed during this period of depression. The bad times have given us opportunity to develop new systems and move forward from the traditional building trade to a building industry, characterised by high productivity. Light-gauge steel framing (LGSF) was introduced into the Swedish market a few years ago and is now established as a competitive alternative to traditional building materials.

13. **Sumit Ghosh, Suhrit Mul, Dipak Kumar Mondal, (2017)" Development of ultrahigh strength cast-grade microalloyed steel by simple innovative heat treatment techniques for industrial applications".**

Aim of the present study is to devise simple and economical heat treatment methods to develop ultrahigh strength cast-grade microalloyed steel for industrial applications. Typical heat treatment cycles were designed on the basis of critical temperatures, Ac3 & Ac1 (obtained through Thermo-Calc software) and TTT/CCT curves (constructed using JMatPro software). In this work, homogenized annealed samples have been subjected to typical heat treatment cycles that consisted of repeated short-duration holding at different critical temperatures followed by forced air cooling/ice-brine quenching. The two cycles heat treatment (i.e., holding for 6 min at Ac3+50°C followed by forced air cooling + holding at intercritical zone for 20 min followed by ice-brine quenching) has resulted a significant increase in the strength with a significant amount of ductility (UTS=1545MPa, hardness=446HV, 9% elongation). This could be attributed to the development of a typical complex microstructure consisted of degenerate pearlite, fragmented cementite and finely dispersed NbC/VC in the matrix of spider network like martensite. Development of such typical microstructure has been enlightened through the analysis of divorced eutectoid transformation and diffusion controlled mechanisms. Therefore, these heat treatments techniques could be extremely useful to develop ultrahigh strength cast grade steels economically for structural/industrial applications.

14. W. Leonardo Cortés-Puentes, Dan Palermob, AlaaA bdulridha and Muslim Majeed, (2016) " Compressive strength capacity of light gauge steel composite columns"

The axial compressive strength capacity of concrete-filled light gauge steel composite columns was assessed through an experimental program involving twelve long and fourteen stub columns with width-to-thickness ratio of 125 for the encasing steel section. A comparison between concrete-only and confined stub columns demonstrated that the stub column experiences an increase of strength of up to 16% duet confinement. The compressive strength contribution of the light gauge steel section was limited by local buckling. Specifically, the steel-only stub column section slacking the concrete core experienced, on average, approximately 33% of its full compressive strength. The full-scale composite column sill strutted at the axial compressive strength capacity was controlled by end bearing capacity and local buckling of the light gauge steel.

15. Robert Baldock, (2017) " Structural Optimisation In Building Design Practice"

This thesis aims to contribute to the reduction of the significant gap between the state-of-the art of structural design optimization in research and its practical application in the building industry. The hypothesis that optimization can be successfully and appropriately applied in practice through consideration of industry specific issues is explored. The research has focused on structural topology optimization, investigating three distinct methods through the common example of bracing design for lateral stability of steel building frameworks. The research has been aided by collaboration with structural designers at Arup. It is shown how Evolutionary Structural Optimization can be adapted to improve applicability to practical bracing design problems by considering symmetry constraints, rules for element removal and addition, as well as the definition of element groups to enable inclusion of aesthetic requirements. Size optimization is added in the optimization method to improve global optimality of solutions.

3. *METHODOLOGY*

Design considerations as per IS 875:1987 PART I, II, III have been employed in calculating loads. A-type geometry is explored in the work.

- ✓ **Design Wind Speed (Vz)**

Design Wind Speed depends upon

(a) Risk level

(b) Terrain roughness, height and size of structure

(c) Local topography.

It can be mathematically expressed as follows:

$$V_z = V_b . K_1 . K_2 . K_3 \quad \text{……………………(1)}$$

- ✓ **Design Wind Pressure (Pz)**

The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity:

$$P_Z = 0.6 . V_Z 2 \quad \text{…… (2)}$$

Where,

Vz = design wind speed at any height z in m/s,

Vb = basic wind speed in m/s,

K1= probability factor (risk coefficient),

K2= terrain, height and structure size factor,

K3= topography factor,

Pz = design wind pressure in N/m2 at height z,

Vz = design wind velocity in m/s at height z.

- ✓ **Wind Pressures and Forces on Buildings/Structures**

For clad structures, it is necessary to know the internal pressure as well as the external pressure. Then the wind load, F, acting in a direction normal to the individual structural element or cladding unit is:

$$F = (C_{pe} - C_{pi}) . A . P_z \quad \text{……….(3)}$$

Where,

Cpe = external pressure coefficient,

Cpi = internal pressure coefficient,

A = surface area of structural element or cladding unit, and

Pz = design wind pressure.

4. *CONCLUSION*

Light Gauge steel has become a competitive building material as a result of industry wide efforts. To ensure sustained market growth for cold-formed steel in building construction, AISI and the Steel Market Development Institute will continue to play an important role to increase collaboration between different organizations, to improve the design specification, and to enhance the image and awareness of cold-formed steel in the marketplace. The American Iron and Steel Institute has been and will remain at the forefront of developing codes and standards to pave the way for cold-formed steel to enter a new era.

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