# Structural Performance of Cold Form Steel Truss and its Comparison With Hot Rolled Steel

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**Abstract**

**This paper presents analytical observation results on the performance of cold formed steel truss and hot rolled steel truss. Two trusses of same dimensions and same type with different materials have been studied and compared. Both the materials are compared on the basis of fast, better, and economic construction. One truss is completely designed and analyzed in hot rolled steel while the same model is designed in cold formed steel. Both the trusses are designed in ETABS. Results of the present study would be handy in designing a truss that leads to optimal use of material. In constructions of residential and industrial buildings, the use of cold-formed steel (CFS) structures has now grown-up considerably, and now it is becoming a suitable alternative to general and conventional methods due to its massive advantages, like it is very light weight, it has high quality, and ease of construction. The present research targets to evaluate the lateral performance of cold formed steel truss systems. This research is crucial for improving the design of cold-formed steel (CFS) truss structures because there is unavailability of adequate information presently in the available codes and standards.**

***Keywords :*** **Cold Formed Steel, ETABS , Hot Rolled Steel, Light weight**

## I. INTRODUCTION

A truss is a structure consisting of a stable and systematic arrangement of meager interconnected members. Every member of the truss is straight and is linked or connected at joints. Members of truss are arranged in such an outline so that they produce competent, light weight, load-bearing members. Joints of truss carry zero moments because members are connected by frictionless pin. Therefore, truss members carry only axial forces which are tensile or compressive. Trusses have more use in recent construction and are used normally in buildings which support roofs, floors, and internal loadings. Steel truss structures are most commonly used in industrial buildings. The sections used for steel trusses are in general angle sections, T-sections, C-channel sections, square hollow sections, pipe sections etc. The main purpose is to reduce the cost of the project and fulfill structural requirement in any case of construction of structure. Hence, it becomes essential to optimize the structure to accomplish the economical requirement. Various constraint limits of the structure should satisfy stress and local stability conditions for optimal design of a structure. In earlier period, many researchers had performed research on optimization of truss.

Cold-formed, light-gauge steelworks have been one of the most prolific areas for research and improvement in the field of structural steel work over the last few decades leading straight to greatly increased use of these members as primary structural elements. While the forming process for cold-formed sections allows a lot greater freedom than is the case for heavier hot-rolled members, considerable inventiveness in cross sectional

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shapes has been possible, bringing with it the benefits of more competent material usage but also the challenge of need to consider more complex structural response. This arises from two basic properties of the product, (a) the slimness of the plate elements in typical structural shapes; and (b) the complexity of the structural behavior resulting from both this thinness and the greater variety and complexity of shapes possible in the cold-rolling process. CFS sections are comparatively lighter in weight than hot rolled steel sections. CFS has no definite sections, so it can be moulded into any desired sections and as it can be moulded into any section, the aesthetic view of the structure can greatly be enhanced.

## II. METHODOLOGY

The current study is incorporated in the design of a Truss located in Aurangabad City. The structure is a workshop of mechanical works. The actual structure is a Hot Rolled Steel Truss of four spans each of 20 m length and has a height of 8 m. In this study, a typical Cold Form Steel Truss frame of 20 m span is taken and the design is made out by taking into consideration wind load as critical load.

The designs are done in agreement with the Indian Standards and by using structural analysis and design software ETABS. Hot rolled frame is also designed for the identical span, taking into consideration an economical roof truss configuration. Both the designs are compared to find out the efficient output.

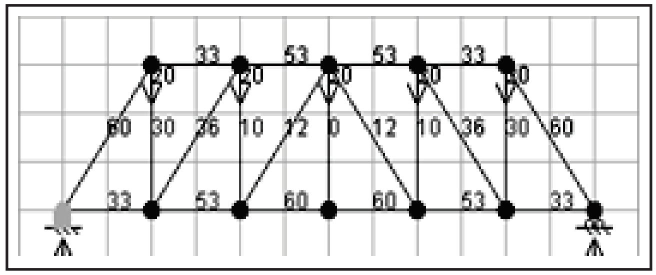


**Fig. 1. Pattern of the Force Spread out in Howe Truss**

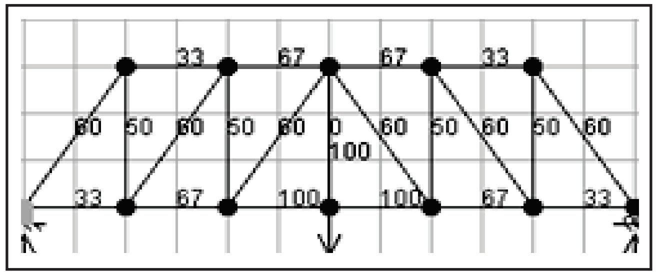


**Fig. 2. Load Distribution Pattern in Howe Truss**

### *A. Truss Type and Properties*

The type of truss taken for this paper is Howe Truss. A Howe Truss is a truss formed by number of chords, verticals, and diagonals whose diagonal members are in compression and whose vertical members are in tension. The Howe truss was developed in 1840 by William Howe. After that it was widely used in mid to late 1800s as bridge. This truss was developed and designed by


| | Hot rolled channel | Cold rolled channel | Cold rolled channel | Cold rolled channel |
|---|---|---|---|---|
| $A$ | 1193 $mm^2$ | 1193 $mm^2$ | 1193 $mm^2$ | 1193 $mm^2$ |
| $I_{xx}$ | $1.9 \times 10^6$ $mm^4$ | $2.55 \times 10^6$ $mm^4$ | $6.99 \times 10^6$ $mm^4$ | $15.53 \times 10^6$ $mm^4$ |
| $Z_{xx}$ | $38 \times 10^3$ $mm^3$ | $43.4 \times 10^3$ $mm^3$ | $74.3 \times 10^3$ $mm^3$ | $112 \times 10^3$ $mm^3$ |
| $I_{yy}$ | $0.299 \times 10^6$ $mm^4$ | $0.47 \times 10^6$ $mm^4$ | $1.39 \times 10^6$ $mm^4$ | $3.16 \times 10^6$ $mm^4$ |
| $Z_{yy}$ | $9.1 \times 10^3$ $mm^3$ | $11.9 \times 10^3$ $mm^3$ | $22 \times 10^3$ $mm^3$ | $33.4 \times 10^3$ $mm^3$ |

**Fig. 3. Some CFS Sections**

William Howe in 1840. It generally used wood in construction and was suitable for grater spans than the Pratt truss. As a result, it became very well-liked and was measured as one of the best designs for railroad bridges late back in the day.

### B. Pattern of the Force Spread Out in Howe Truss

Fig. 1 and Fig. 2 show the pattern of force spread out as the Howe Truss is subjected to load. The earlier diagram shows the load being applied along the entire top of the bridge. The subsequent figure shows a localized load in the center of the truss (bridge). In mutual cases, the total load is 100 units. So, the numerical values can be considered as a percentage of the total load. Fig.1 shows pattern of the force spread out in Howe Truss and Fig. 2 shows load distribution pattern in Howe Truss.

### C. Some CFS Sections

CFS sections are prepared from structural class sheet steel that are fashioned into C-sections and few other shapes by roll forming the steel all the way through a series of dies. No heating is necessary to outline the shapes, unlike hot-rolled steel members. Therefore, the name cold-formed steel. Fig. 3 shows some CFS sections.

### D. Traditional Steel Buildings

Traditional steel buildings are generally low rise steel structures having truss as a roofing systems [7]. Depending upon the pitch of the truss, different types of roof trusses can be used for these structures. Fink type truss can be used for large pitch; for medium pitch, Pratt type truss is generally used, and Howe type truss can be used for small pitch [5]. Numerous compound and combination type of economical roof trusses can also be chosen by considering the utility. Regular hot-rolled section members are usually used in the truss elements with gusset plates [6]. Skylight can be pledges for day lighting and as per [5] additional day lighting, North light type truss can be used. The choice criterion of roof truss also includes the fabrication and transportation methods, climatic conditions, aesthetics, slope of the roof etc.

## III. TRUSS'S MODELLING AND ANALYSIS

Fig. 4 shows the type of Howe Truss that is analyzed in the current study, in which a span of 20 m is taken and height of 4m is considered for all cases. Working, potting, and modeling is carried out in ETBAS software. Used properties as well as geometrical parameters of currently used Howe Truss are mentioned in Table II and Table IV simultaneously. In Table I, considered loading condition in present study is shown.

## IV. CONSIDERED LOADINGS

Calculation of loadings for the current structure can be performed by taking reference of IS: 1893 – 2000 and IS: 875 – 1987. Dead load, wind Load, snow load, live load, earthquake load, erection load, accidental load crane load, etc. are the loads acting on the structure includes [1]. For the present structure, wind load is more significant than earthquake load as per [9]. Therefore, for design purpose, load combinations of dead load, live load, crane load, and wind load are incorporated.

### A. Dead Load

Dead load consists of self-weight of the structure, G.I. sheets, weights of roofing, bracings, and other accessories, sag rods, gantry girder, purlins, crane girder as in [2]. Dead load of 8.8 kN/m distributed entirely over the roof does not include self-weight. During designing the structure in Etabs, this load is applied as point load at the joints. The load of 8.8 kN is applied as equivalent point load over at intermediate panel points and half the value is at end panel points over the roof truss. In reference [2], detailed procedure for dead load calculation is given.

### B. Live Load

As per IS: 875 (Part 2) – 1987, intensity of 17.76 kN/m of uniformly live load is acting on the truss's rafter. Live load is applied as point load at panel points for truss

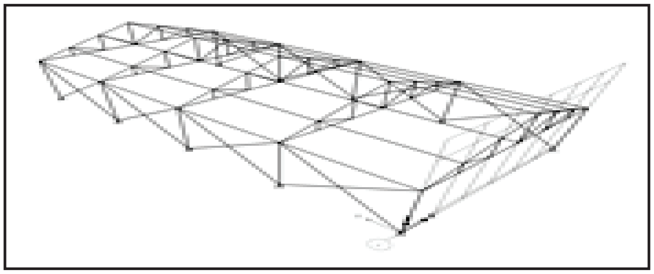

**Fig. 4. Howe Truss Model**

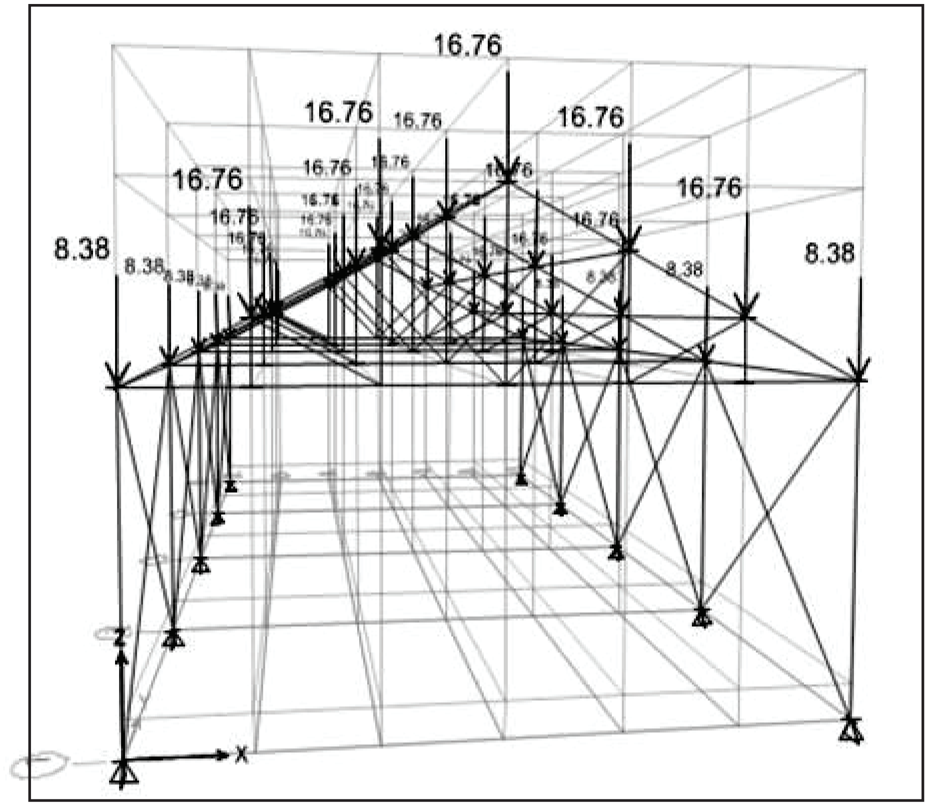


**Fig. 5. Howe Truss Story Details**

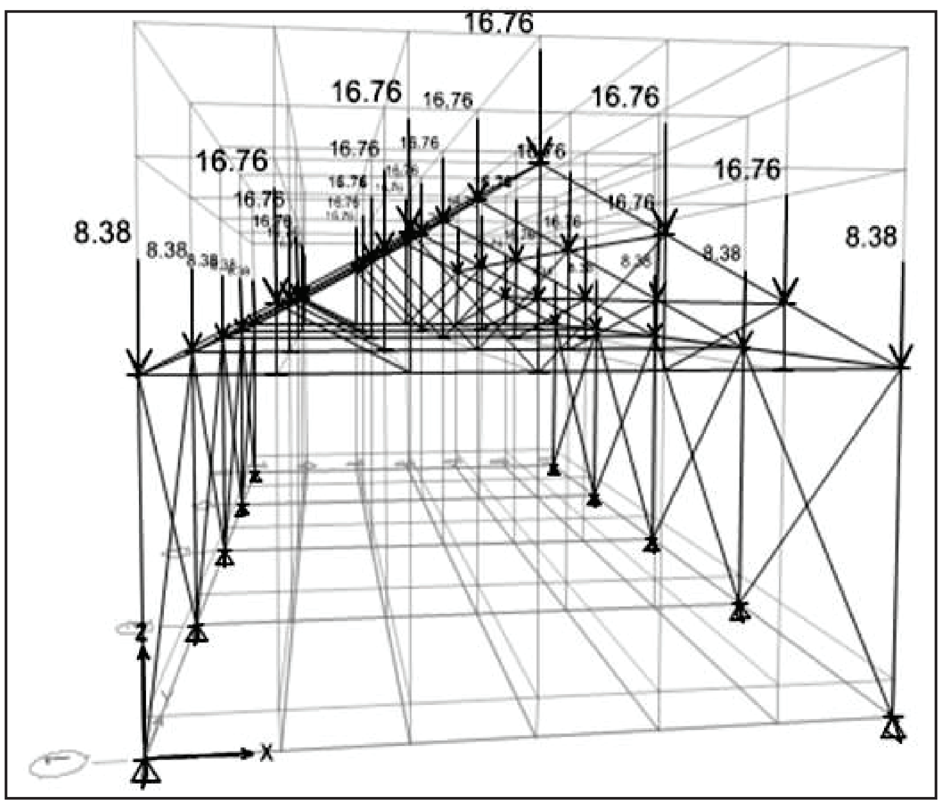


**Fig. 6. Howe Truss Story Forces**

similar to dead load, and its intensity is 16.76 kN which is acting at intermediate panel points, and half of its value is acting at end points. Procedure for calculation of live load calculation is as per [3].

### *C. Wind load*

For calculation of Wind Load, referred code is IS : 875 (Part 3) – 1987. For current given location of building, the basic wind speed is 39 m/s [9]. The wind load is provided as UDL over the truss and over the roof acting outward, passing in [8]. According to the wind case for side walls, the wind load is applied as UDL acting inward or may be outward to the walls. Table II shows the wind loads acting over the roof and side walls comes in four different combinations. Fig. 5 shows Howe Truss Story details. Fig. 6 shows Howe Truss Story forces.

## V. USED LOAD COMBINATIONS

Used load combinations are considered with reference to IS: 800 – 2007. For analysis purpose, 16 different load combinations are taken in both the materials, as per reference [1] and they are mentioned in Table I.

## VI. ETABS PROCEDURE

ETABS software is a structural design and analysis software which is useful for modeling, analysing, and later in designing of structure. Standards of several countries including Indian standard are followed in this software. The procedures are simple and given in chronological order like first modeling the structure, then applying all needed properties, all possible specifications, loads are considered, and load combinations are taken. Later, analysis is done and finally structural design is prepared. For three dimensional model generation, analysis and multi-material designs purpose, this software is an effective and user-friendly tool.

## VII. RESULTS AND DISCUSSION

The ETABS software which is very effective and user-friendly is used for structural analysis purpose anddesign of the Truss. Initially, a CFS Truss is chosen

**TABLE I.**

**LOAD COMBINATION DETAILS**

| Combination | Combo or Load Case | SF (Scale Factor) | Type | Auto |
|---|---|---|---|---|
| 1.5D | DL | 1.5 | Linear Add | No |
| 1.5D+1.5L | DL | 1.5 | Linear Add | No |
| 1.5D+1.5L | LL | 1.5 | | No |
| 1.2D+1.2L+0.6W | DL | 1.2 | Linear Add | No |
| 1.2D+1.2L+0.6W | LL | 1.2 | | No |
| 1.2D+1.2L+0.6W | WL | 0.6 | | No |
| 1.2D+1.2L-0.6W | DL | 1.2 | Linear Add | No |
| 1.2D+1.2L-0.6W | LL | 1.2 | | No |
| 1.2D+1.2L-0.6W | WL | -0.6 | | No |
| 1.2D+1.2L+1.2W | DL | 1.2 | Linear Add | No |
| 1.2D+1.2L+1.2W | LL | 1.2 | | No |
| 1.2D+1.2L+1.2W | WL | 1.2 | | No |
| 1.2D+1.2L-1.2W | DL | 1.2 | Linear Add | No |
| 1.2D+1.2L-1.2W | Live | 1.2 | | No |
| 1.2D+1.2L-1.2W | wind | -1.2 | | No |
| 1.5D+1.5W | DL | 1.5 | Linear Add | No |
| 1.5D+1.5W | wind | 1.5 | | No |
| 1.5D-1.5W | DL | 1.5 | Linear Add | No |
| 1.5D-1.5W | wind | -1.5 | | No |
| 0.9D+1.5W | DL | 0.9 | Linear Add | No |
| 0.9D+1.5W | wind | 1.5 | | No |
| 0.9D-1.5W | DL | 0.9 | Linear Add | No |
| 0.9D-1.5W | wind | -1.5 | | No |
| 1D | DL | 1 | Linear Add | No |
| 1D+1L | DL | 1 | Linear Add | No |
| 1D+1L | Live | 1 | | No |
| Envelope | DL | 1 | Envelope | No |
| L is for Live load | | | | |
| D is for DL Load | | | | |

**TABLE II.**

**PROPERTIES OF HOWE TRUSS**

| S. No. | Parameters | Values |
|---|---|---|
| 1 | Member | 13 |
| 2 | Materials | Steel |
| 3 | Joints | 12 |
| 4 | Poison's Ratio | 0.287 |
| 5 | Density | 7,700 $kg/m^3$ |
| 6 | Modulus of Elasticity | 203.39 GPa |
| 7 | Supports | Pinned support |

**TABLE III.**

**GEOMETRICAL PARAMETERS OF HOWE TRUSS**

| S. No. | Span (m) | Height (m) |
|---|---|---|
| 1 | 20 | 8 |

**TABLE IV.**

**BASE REACTIONS**

| Load Case/ Combo | FX kN | FY kN | FZ kN | MX kN-m | MY kN-m | MZ kN-m | X m | Y m | Z m |
|---|---|---|---|---|---|---|---|---|---|
| DL | 0 | 0 | 1,676.1418 | 33,731.1756 | -16,606.0418 | 0 | 0 | 0 | 0 |
| Live | 0 | 0 | 502.8 | 10056 | -5,022.972 | 0 | 0 | 0 | 0 |
| wind 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| wind 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1.5D | 0 | 0 | 2,514.2126 | 50,596.7633 | -24,909.0627 | 0 | 0 | 0 | 0 |
| 1.5D+1.5L | 0 | 0 | 3,268.4126 | 65,680.7633 | -32,443.5207 | 0 | 0 | 0 | 0 |
| 1.2D+1.2L+0.6W Max | 0 | 0 | 2,614.7301 | 52,544.6107 | -25,954.8165 | 0 | 0 | 0 | 0 |
| 1.2D+1.2L+0.6W Min | 0 | 0 | 2,614.7301 | 52,544.6107 | -25,954.8165 | 0 | 0 | 0 | 0 |
| 1.2D+1.2L-0.6W Max | 0 | 0 | 2,614.7301 | 52,544.6107 | -25,954.8165 | 0 | 0 | 0 | 0 |
| 1.2D+1.2L-0.6W Min | 0 | 0 | 2,614.7301 | 52,544.6107 | -25,954.8165 | 0 | 0 | 0 | 0 |
| 1.2D+1.2L+1.2W Max | 0 | 0 | 2,614.7301 | 52,544.6107 | -25,954.8165 | 0 | 0 | 0 | 0 |
| 1.2D+1.2L+1.2W Min | 0 | 0 | 2,614.7301 | 52,544.6107 | -25,954.8165 | 0 | 0 | 0 | 0 |
| 1.2D+1.2L-1.2W Max | 0 | 0 | 2,614.7301 | 52,544.6107 | -25,954.8165 | 0 | 0 | 0 | 0 |
| 1.2D+1.2L-1.2W Min | 0 | 0 | 2,614.7301 | 52,544.6107 | -25,954.8165 | 0 | 0 | 0 | 0 |
| 1.5D+1.5W Max | 0 | 0 | 2,514.2126 | 50,596.7633 | -24,909.0627 | 0 | 0 | 0 | 0 |
| 1.5D+1.5W Min | 0 | 0 | 2,514.2126 | 50,596.7633 | -24,909.0627 | 0 | 0 | 0 | 0 |
| 1.5D-1.5W Max | 0 | 0 | 2,514.2126 | 50,596.7633 | -24,909.0627 | 0 | 0 | 0 | 0 |
| 1.5D-1.5W Min | 0 | 0 | 2,514.2126 | 50,596.7633 | -24,909.0627 | 0 | 0 | 0 | 0 |
| 0.9D+1.5W Max | 0 | 0 | 1,508.5276 | 30,358.058 | -14,945.4376 | 0 | 0 | 0 | 0 |
| 0.9D+1.5W Min | 0 | 0 | 1,508.5276 | 30,358.058 | -14,945.4376 | 0 | 0 | 0 | 0 |
| 0.9D-1.5W Max | 0 | 0 | 1,508.5276 | 30,358.058 | -14,945.4376 | 0 | 0 | 0 | 0 |
| 0.9D-1.5W Min | 0 | 0 | 1,508.5276 | 30,358.058 | -14,945.4376 | 0 | 0 | 0 | 0 |
| 1D | 0 | 0 | 1,676.1418 | 33,731.1756 | -16,606.0418 | 0 | 0 | 0 | 0 |
| 1D+1L | 0 | 0 | 2,178.9418 | 43,787.1756 | -21,629.0138 | 0 | 0 | 0 | 0 |
| Envelope Max | 0 | 0 | 1,676.1418 | 33,731.1756 | -16,606.0418 | 0 | 0 | 0 | 0 |
| Envelope Min | 0 | 0 | 1,676.1418 | 33,731.1756 | -16,606.0418 | 0 | 0 | 0 | 0 |

from the structure and complete design. Then the other frame is analysed and designed using the Hot Rolled material's steel Truss. Table III shows geometrical parameters of Howe Truss and Table IV shows the base reaction of truss.

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