Structure Analysis of Cold-Formed Steel Roof Truss Post Office Branches Loa Janan

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Abstract. Steel is one of the most widely used construction material for structural systems in modern construction. In recent years, Cold formed steel (CFS) sections- which is being another major type of steel sections and found to be an alternative to the familiar Hot rolled steel sections. The purpose of this research is to choose the best CFS products in terms of strength and safety which use for Loa Janan post office. This study begins by collecting primary and secondary data. Then look for references in CFS products in the field. In this study there is 4 CFS brands (Taso, Cici, Truss, and Kaso product). Than the sample of product will be testing in the laboratory. The loading is carried out guide [1]. Than to analyse of the CFS frame use [2]. For model using SAP 2000 application. The material used in this study were steel profile C 75 75 0.75 to tension members. From the results of the analysis, it can be concluded that of the 4 steel materials being studied all can withstand the load. However, the CFS brand Taso has the highest maximum stress of 46.27 KN. while the smallest Truss brand is 0.17 KN.

Keywords: Truss, cold-formed, roof

1. Introduction
Cold-formed steel has been extensively used in residential construction in Indonesia in recent years. With a high strength-to-weight ratio, cost-effective, non-combustible, fully recyclable, durable and dimensionally stable cold-formed steel framing results in better performance as the primary structural system in residential construction, particularly in high wind and seismic regions. Steel trusses also have great advantages in speeding up the construction process and reducing labour costs, since the lightweight of cold-formed steel makes such trusses much simpler to erect in comparison to wood trusses. As an alternative material to conventional wood truss construction, cold-formed steel trusses for residential roof systems capitalize on the many inherent benefits of steel and have great potential in both residential and commercial construction. However, because there are no regulations issued by the government about cold frame such as other materials like conventional steel, so it is necessary to do a careful analysis in terms of strength, durability, ductility and also other mechanical properties materials. At first, KPC Loa Janan post office roof used wood but it was damaged so it would be changed using cold frame structure. The length of the roof truss is 9 meters, with the cold frame profile used is C 75.75.75. Because of the span too long so it needs research to learn the strength of the roof structure. The objectives of the research are knowing the security of the KPC Loa Janan Post Office building roof structure and also determine the cheapest but strong cold frame structure.

2. Materials and Methods

2.1. Lightweight Steel Roof Truss
The lightweight steel roof truss is a framework for the roof of the truss or called truss made of steel as a substitute for conventional roof truss made of wood. The lightweight steel roof truss is made for easy assembly and construction. Although thin mild steel has a degree of the tensile strength of 550 Mpa, while ordinary steel is around 300 Mpa. The tensile strength and stress are for changing the thin shape [3].

2.2. Cold Frame
Cold-formed steel (CFS) steel structure profiles are structural quality components of steel sheets formed by certain models with a press-braking or roll forming process (Figure 1). Temperature is not required in the process of forming (unlike hot-rolled steel), therefore it is called cold-formed. Cold-formed steel is usually a thin component, lightweight, easy to produce, and inexpensive compared to hot-rolled steel.

![Figure 1. The process of forming steel profiles [3]](image)

Research on comparisons between wooden roof truss and light steel truss had previously been done by [4]. From the results of his research, it was found that the maximum stress that occurs in mild steel is 544.01 Mpa. While wood has maximum stress of 440.26 MPa. From the cost for a span of 7 meters it was concluded that the costs required when using mild steel are cheaper when using wood (grinding wood).

2.3. Field Steel Frame Stability
Trunk frame instability can be caused by unstable geometric shapes, excessive loads, one of the stems has failed and due to differences between planning/analysis and practice (implementation). The force working on the frame is the axial force, where the axial force can be classified into compressive and tensile forces. Excessive compressive force on the stem can cause the stem to bend (local or global pitch). If the load continues to increase instability will occur in the stem, which in turn will happen structural failure.

A computer-based optimal design approach for residential roof trusses using cold-formed steel C-sections is presented. The truss design is based on CSA S136-94 and the truss design guide published by the American Iron and Steel Institute and the Canadian Sheet Steel Building Institute. A genetic algorithm was adopted to obtain the minimum cost design with consideration to truss topology and member size simultaneously. The presented design examples demonstrate the applicability and efficiency of the proposed approach [5]. Investigation on the optimisation of CFS members subjected to flexural capacity and results [6]. 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 possess 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. Compress Members
The structural components which bear the factored axial tensile force, \( N_u \), must meet:

\[
N_u \leq \phi N_n
\]  
(1)

Where:
- \( \phi \): Reduction factor;
- \( N_n \): Nominal tensile strength whose measurement is taken as the lowest value in some of the equations below:

1. Nominal tensile strength based on yield conditions on the gross cross-section:

\[
N_n = A_g f_y
\]  
(2)

2. Nominal tensile strength based on a fracture on the effective cross-section:

\[
N_n = A_e f_u
\]  
(3)

Where:
- \( A_g \): Gross cross-sectional area (mm\(^2\));
- \( A_e \): Effective cross-sectional area (mm\(^2\));
- \( f_y \): Yield stress (MPa);
- \( f_u \): Ultimate stress (MPa).

2.5. Tension members
Design due to compressive forces

\[
N_u \leq \phi N_n
\]  
(4)

Where:
- \( \phi \): Reduction factor;
- \( N_n \): Nominal tensile strength of compressive structures;

This research begins with taking secondary and primary data. Secondary data in the form of design is as-built drawings. Whereas the primary data consisted of the strength of tensile steel data obtained from the results of tensile steel testing carried out in laboratories, civil engineering department, State Polytechnic of Samarinda. There are four light steel products tested, it’s Taso (TO), Cici (CI), Truss (TS) and Kaso (KO) brands. From the test, it’s used for input material in the SAP 2000 program. The output SAP result from modelling will be checked by theoretical analysis. 

The completed of research stages carried out following flow chart below (Figure 2):
3. Result and Discussion

The roof model of loajanan post office (figure 3). There is use a cold-formed for the roof structure.

![Figure 3. Roof structure Post office branch Loajanan](image)

Shown in figure 3 can be seen that the cover of the roof using multi roof, the trusses using cold-formed steel C 70.70.7. Span steel trusses is 9 meters, and the distance between trusses is 1 meter.

3.1. Material

Creating steel sample specimens use the standards and specifications [8]. The shape of the specimen is important because we must avoid the occurrence of fractures or cracks in the grip area or the other. So
the purpose shape standardization of the test specimen is that cracks and fractures occur in the gage length area. The picture below is the cold frame material test.

![Figure 4. Steel material testing](image)

| The Brand | fn (KN) | fy (KN) |
|-----------|--------|--------|
| CI        | 616.750| 222.220|
| TS        | 631.167| 227.777|
| KO        | 665.890| 255.557|
| TO        | 702.580| 258.335|

From the table 1, we can see the maximum tensile strength is TO product (616.750 KN), and the small strength tensile is CI product (616.750). The test was conducted at the civil engineering laboratory of State Polytechnic of Samarinda.

### 3.2. Roof Truss Design Model

A cold-formed steel roof truss is a system composed of individual members. In Post office Loajanan, these individual members are commonly C-section, and self-drilling screws are usually used as fasteners to connect the members. To analysis we use SAP 2000 to make roof truss model (Figure 5). Input initial structure data, load condition (dead load include the self-weight of truss as well as roof and ceiling materials, live load and also wind load) doing the structure (Table 2). The three design load cases considered in this model, are:

- Comb 1 : 1,4 Dead Load
- Comb 2 : 1,2 Dead Load + 1,6 Live Load
- Comb 3 : 1,2 Dead Load + 1,6 Live Load + (0.5 Wind Load/0.5 Water Load)

Both chord and web members are C-sections using a yield strength and an ultimate strength from the tensile test result before.

![Figure 5. Truss modelling using SAP 2000](image)
Table 2. Table of loading frame truss

| No of Join | Distance (m) | Dead Load (kg) | Live Load (kg) | Wind Load (kg) |
|------------|--------------|----------------|----------------|---------------|
|            |              | Gording | Roof | Bolt | Total | People | Water | Compress | Pull |
| 1&10       | 0.67545      | 10.2    | 6.75 | 1.70 | 33.04 | 100    | 18.9126 | 1.69     | 6.75 |
| 2&9        | 1.05955      | 15.3    | 10.60| 2.59 | 50.94 | 100    | 29.6674 | 2.65     | 10.60|
| 3&8        | 0.93025      | 10.2    | 9.30 | 1.95 | 40.44 | 100    | 26.047  | 2.33     | 9.30 |
| 4&7        | 1.12495      | 15.3    | 11.25| 2.65 | 49.33 | 100    | 31.4986 | 2.81     | 11.25|
| 5&6        | 0.5788       | 10.2    | 5.79 | 1.60 | 26.78 | 100    | 16.2064 | 1.45     | 5.79 |

3.3. Analysis
A deflection limit of L/360 was used for all load case. From the results of the programming can be seen the force members on the roof truss. The force is divided into two force, there is tensile force member and stress force members. The maximum tensile force member is second member (31.14 KN) and the maximum for stress force is first member (32.23 KN). The completed force members result of program are listed in table 3. Then from the members force, do analysis performed to determine the nominal stress of each product. From the analysis results, the highest nominal stress is found in the Taso product, while the smallest is Cici product. The completed result is shown in Figure 6.

Table 3. Table of members force

| Frame | Members force (KN) | Tensile (+) | Stress (-) |
|-------|---------------------|-------------|------------|
| 1     |                     | -           | 32.23      |
| 2     | 31.14               | -           | -          |
| 3     | -                   | 2.37        | -          |
| 4     | -                   | 30.74       | -          |
| 5     | 2.36                | -           | -          |
| 6     | 28.11               | -           | -          |
| 7     | -                   | 3.72        | -          |
| 8     | -                   | 26.74       | -          |
| 9     | 3.60                | -           | -          |
| 10    | 23.64               | -           | -          |
| 11    | -                   | 4.68        | -          |
| 12    | -                   | 21.62       | -          |
| 13    | 4.17                | -           | -          |
| 14    | 19.16               | -           | -          |
4. Conclusion
From the Calculation of Lightweight Steel Roof Truss Structure. KPC Loa Janan Post Office can be concluded that:

- All cold frame products conducted in the study are still safe to withstand the existing load.
- The maximum nominal stress is Taso product = 46.27 KN and the maximum of tensile stress is Kaso product 284.56 KN.
- From the analysis it can be concluded that the Taso brand CFS products have a better performance than other steel products.

5. References
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