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Research Article

Effectiveness and Shape Design of CFRP Structural Sections in Roof Trusses

Ajimituhuo JL and Abejide OS*

Department of Civil Engineering, Nigeria

***Corresponding author:** Abejide OS, Department of Civil Engineering, Nigeria,

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Abstract

Roof trusses have always been constructed using traditional materials such as timber and steel which have been used in industrial, agricultural and residential structures. This study aims at obtaining further effectiveness which can be attained when Carbon Fibre Reinforced Plastic (CFRP) is used as the structural section materials of a roof truss. A CFRP truss section is compared with the same 350W (AISC 2005) steel truss section subjected to same loading conditions Results indicate that the steel truss withstand deflections more than the CFRP truss in both linear and non linear analysis. The CFRP truss was 77% lighter that the steel truss. It was also concluded that the shape of sections used in steel can be adopted for CFRP structures.

Keywords: CFRP; Roof trusses; FEM and reliability; Structural section; Optimization

Introduction

The roof is the first line of defence between any building and the element, and a good working roof is crucial to the survival of a historic building. However, despite its importance, a roof can be the most neglected part of a building. Many owners never make it to roof level to carry out even the most basic maintenance inspections of the roof fabric and the rain water drainage system. This is usually very unfair unless the builders were certain about the quality of material used for the roofing.

Carbon Fibre Reinforced Polymer (CFRP) is currently used to retrofit and repair structurally deficient infrastructures such as bridges, buildings and roof trusses. These composite materials are gaining recognition in civil engineering as a viable alternative to traditional material. The migration from customary automotive, marine, aerospace and military industries into civil engineering has continued to gain momentum over the last three decades as new civil engineering develops [1].

The main impetus for development of carbon fibres has come from the aerospace industry with its need for a material with combination of high strength, high stiffness and low weight. Recently, civil engineers and construction industries have begun to realize that this material (CFRP) has potential to provide remedies for many problems associated with deterioration and strengthening of infrastructure. Effective use of carbon fibre reinforced polymer could significantly increase the life of structures, minimizing the maintenance requirements [1]. Carbon fibre composites provide an alternative to conventional materials, for example steel, aluminum and fiberglass; for the construction of light weight truss and frame structures which is particularly considered in this study. A steel truss section is compared with CFRP section materials and various advantages of the CFRP were deduced.

Generally, as obtained from various studies and researches, properties and advantages of the characteristic property of Carbon Fibre Reinforced Plastics over conventional materials in structure includes [2]:

a) Corrosion resistance in highly acidic environments

b) Thermal and electrical non conductivity

c) Lightweight (weighs about 80% less than steel)

d) High strength to weight ratio

e) Dimension stability

f) Low maintenance and

g) Custom colours.

Further properties are [1]:

i) Short curing times. This saves time in its application in structures.

ii) High fatigue resistance and generally non bio-degradable.

iii) Non-magnetic

iv) Alkali resistant

v) Displays appreciable bond characteristics in reinforced concrete application.

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However, steel is found to be deficient in most of the above listed advantages of CFRP. Some of those deficiencies that must be considered in using steel sections for roof truss in particular are:

a) Installation complexity: steel is less forgiving of installation errors than traditional materials when used for roofing. Leaks are possible if panel joint are not watertight or if the panel screws are not in the correct place

b) Proximity to corrosion in high acidic environment

c) Thermal and electric conductivity which can pose unnecessary danger during unusual lightning and thunder storms. Also in the case of fire, heat can easily be transmitted via the steel material.

d) Heavy weight of steel material.

In all the above listed factors, the replacement of the steel material in roof truss with Carbon Fibre Reinforced Plastic (CFRP) can be conceived as resourceful idea. This is the main justification of this research.

Scope, Aim and Objectives

The scope of this study covers the effectiveness of Carbon Fibre Reinforced Plastic (CFRP) as a better replacement material for steel in roof trusses. The study highlights the various properties of both materials.

Finite element method using PROKON v2.4 software [3] will be used in running analysis on two designed truss structure built with steel and CFRP. Both trusses assume same section sizes and loading conditions but different materials. Results will be drawn out and comparisons and conclusions would be made.

Limitations of the Study

This topic of effectiveness of CFRP roof truss section over steel is one that cannot be exhausted. There are several parameters and methods which can be used to compare the effectiveness which is not discussed in this study due to limited resources. Also, practical tests were not conducted to know the properties of both materials in order to validate the values we obtained and adopted from literatures and theories. The sources of the values used are properly referenced. Below are some other limitations.

a) There are no much literature on the study of CFRP materials and its application as a roofing material.

b) CFRP materials are quite expensive and therefore, it discourages possibility of practical in research projects.

c) Due to the non-availability of CFRP, high precision and accurate results that can be adopted for real life practicality cannot be guaranteed from this study. This research only probes into the possibility of CFRP as a roof section material and its effectiveness. It is therefore open for development and further research.

CFRP is just a stem out of the whole FRP family. Others include Aramid fibre reinforced plastic (AFRP) and Glass fibre reinforced plastic (GFRP). The difference between them is their fibre material. In CFRP, the reinforcing fibre is carbon fibre. Determining the strength of FRPs has been a bit of argument. This is because fibre/resin combination is what determines the strength (tensile, yield, young's modulus, etc) of the final FRP product which is dependent on the taste of the manufacturer. So there are no specifications yet for the grade of the material. All that is still available is the range of strength that can be adopted for research study. This also is a limitation.

Methodology

PROKON

PROKON is a structural analysis and design suite useful for solving everyday building design problems. The PROKON has two main components with distinct but supplementary functions [3]

The calcpad: This is the main module from where you launch the analysis and design modules. You can use calcpad to build calcsheets with design notes, drawings and equations.

The analysis and design modules: These individual modules can be used to analyse and design typical structural and geotechnical elements. Design output can be sent to calcpad and appended to your calcsheet.

Frame analysis

Frame can be used for the analysis of 2D and 3D structures. By selecting the domain, frame input can be limited or expanded to include various degrees of freedom:

a. Plane Frame: Analysis of a frame in a vertical (X - Y) plane.

b. Grillage: Analysis of a structure in a horizontal (X - Z) plane.

c. Space Frame: Analysis of three-dimensional structures made up of beam and/or shell elements and design of concrete shells.

d. Space Truss: Analysis of three-dimensional trusses where only axial forces are considered.

Finite element analysis

Frame allows one to use finite shell elements and solid elements alongside normal beam elements. Shell elements enable one to model the combination of plate bending and membrane action in 3D, and solid elements provides for complex 3D stress analysis. For easy modelling of plate bending in concrete slabs, one may prefer using the Finite Element Slab Design module instead.

Linking with design

Frame analysis results can be post-processed using many steel and concrete design modules. One can fast-track the design of a steel portal frame, its connections and concrete footings from within Frame.

Analysis modes

The following types of analysis are possible in PROKON:

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Linear analysis: Basic linear elastic analysis. A linear analysis is normally sufficient for the static analysis of a frame or truss with negligible sway. This analysis mode in particular is the one considered for the study.

Second order analysis: Choose this mode to include p-delta effects in the analysis. This option is recommended for structures where sway may have a marked effect on the member forces, e.g. portal frames. The second order analysis is an iterative procedure. The total strain energy of the frame is calculated after each iteration. The analysis is deemed to have converged once the total strain energy of two sequential iterations differs by less than the specified tolerance. If convergence was not possible, e.g. structural instability due to buckling of critical members, a message to that effect will be displayed.

Non linear analysis: Choose this mode where non-linear effects and large deflections may be expected or where second order analysis might not provide sufficient accuracy. Loading is applied in a series of steps and an iterative analysis is carried out at each step so that the forces in the deflected structure at that point balance with the applied loading.

Modal analysis: For calculating the natural modes of vibration. The modal analysis is an iterative procedure during which several sets of trial vectors are selected and evaluated. The process takes relatively long to complete and it is therefore recommended that the structure size be limited to a few hundred nodes. One can specify the number of mode shapes to be calculated and other dynamic analysis parameters.

Harmonic analysis: Choose harmonic analysis to determine the response of the frame to harmonic loading. Load amplitudes are entered exactly like static nodal and element loads. One can enter a load frequency and phase angle for each harmonic load case. The first step of a harmonic analysis is the calculation of the frame's natural modes of vibration. Therefore, if preceded by a modal analysis, the results of that analysis are re-used and only the harmonic response calculated. The harmonic response is taken as the sum of the square (SSRS) of the maximum modal responses, a method that is considered fundamentally sound when modal frequencies are well separated. When frequencies of major contributing modes are very close together, the SSRS method can give poor results.

Earthquake analysis: Use this option to calculate the response of the frame to the specified seismic acceleration parameters. Nodal and element loads entered are treated as static loads. The analysis procedure starts by calculating the frame's natural modes of vibration. Therefore, if preceded by a modal analysis, the results of the modal analysis are re-used and only the seismic response calculated.

Buckling analysis: Use this option to determine the buckling load factors and mode shapes for each load case or combination. Being the critical case, the first buckling mode shape is normally the only one of interest.

For the scope of this study, we will be concentrating on linear and modal analysis.

The PROKON Interface

The figure below shows the sample of the subdivided warren roof truss as it is in the PROKON software interface during input. The tables below gives a brief of some of the inputs made into the software before analysis (Figure 1 and Table 1 & 2).

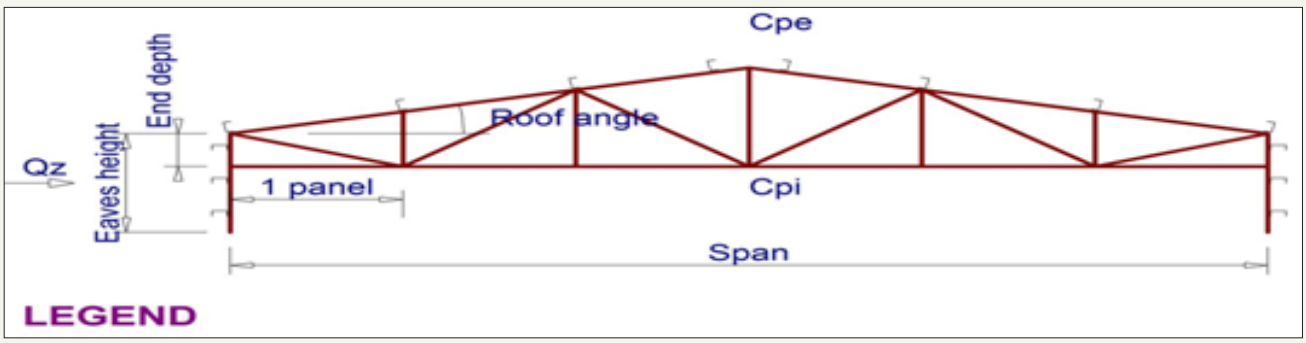

Figure 1:

Table 1: Configuration.

Span (m)	18
Eaves Height (m)	2
No. of Panels	8
Fixity Left (XYZxyz)	
Fixity Right (XYZxyz)	
No. of Truss in Line	1
No. of Bays	1
Bay Spacing (m)	1
Truss End Depth (m)	5
Material	Steel 350W/CFRP

Table 2: Designation.

Top Chord	100x100x8
Bottom Chord	90x90x8
Vertical	70x70x6
Diagonal	60x60x6

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Examples, Analysis and Results

In this chapter the results obtained from the finite element analysis using PROKON is attached. Several variations between the steel section materials and the CFRP section materials were observed. From each of the categories of the result, several differences were obtained between the results of CFRP structural sections and steel structural section material in roof truss. The details of the geometry, type of truss considered, loading conditions and all necessary structural section inputs are given in the PROKON (FEM) result attached to this chapter.

The research is based on several assumptions which are stated in the section above. The results obtained from both materials were different and comparable because of the variation of the basic intrinsic properties of both materials edited into the PROKON section table (refer to PROKON INTERFACE AND TABLES), even though both structures were subjected to the same loading conditions.

Results

Figure 2-24 and Table 3

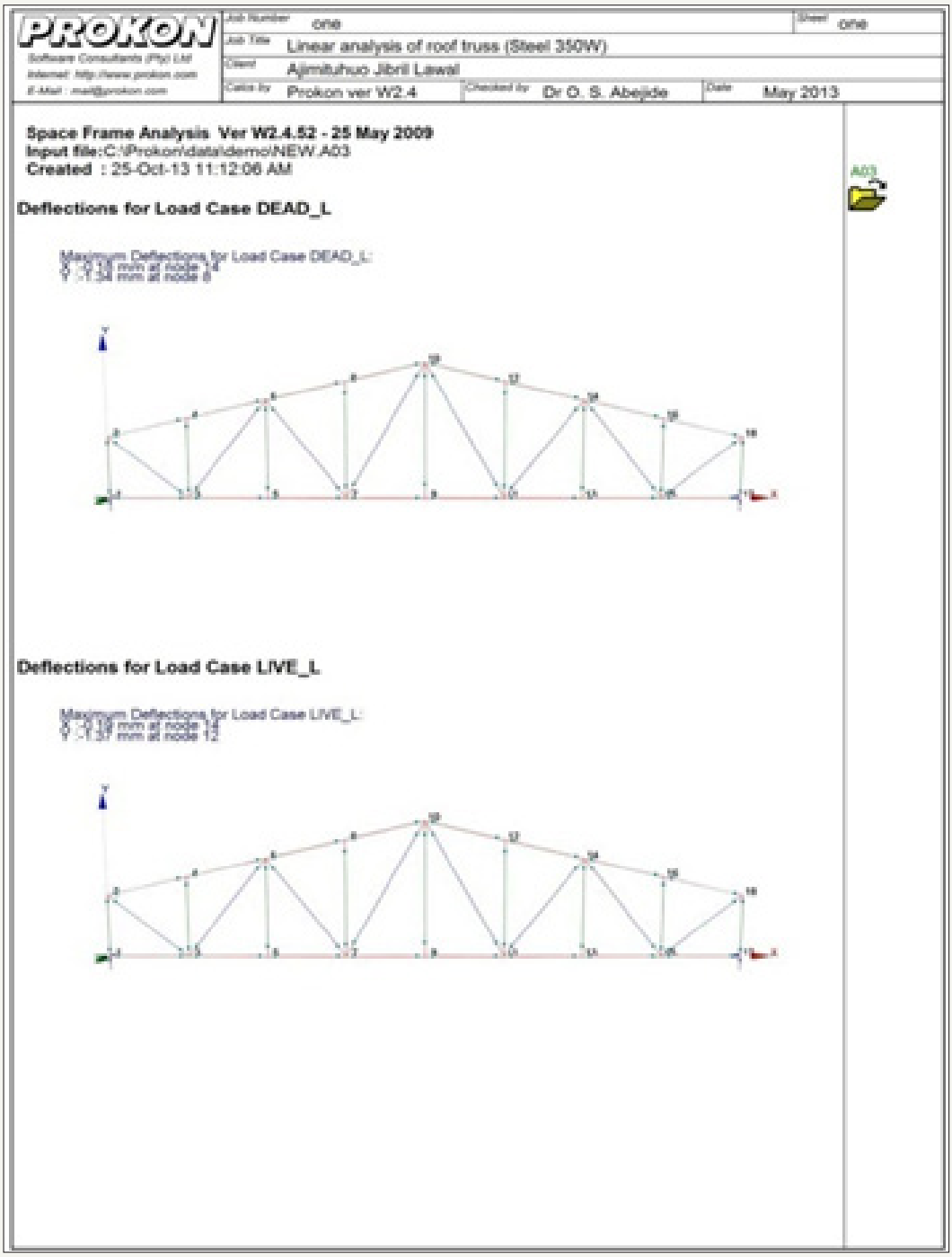

Figure 2:

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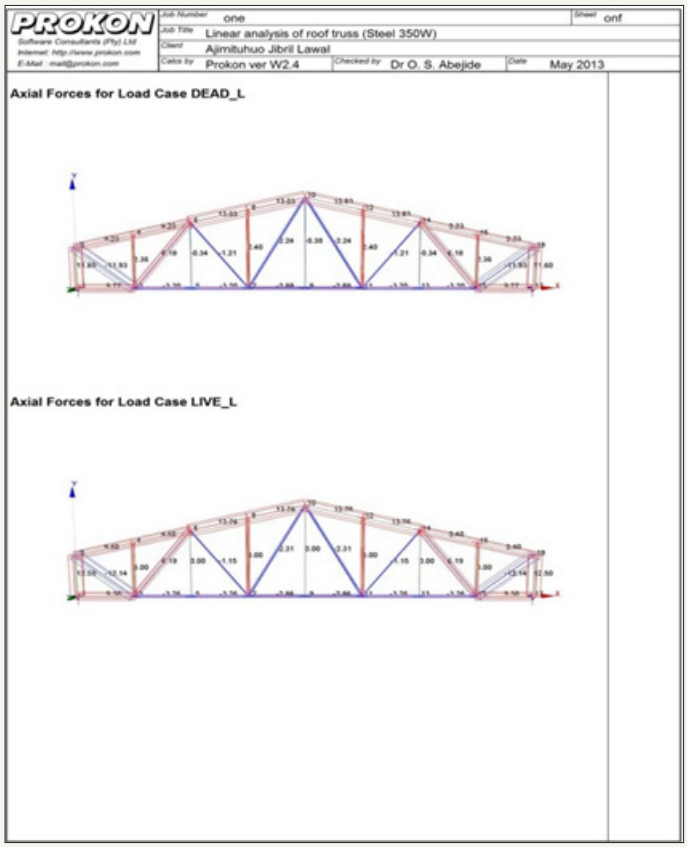

Figure 3:

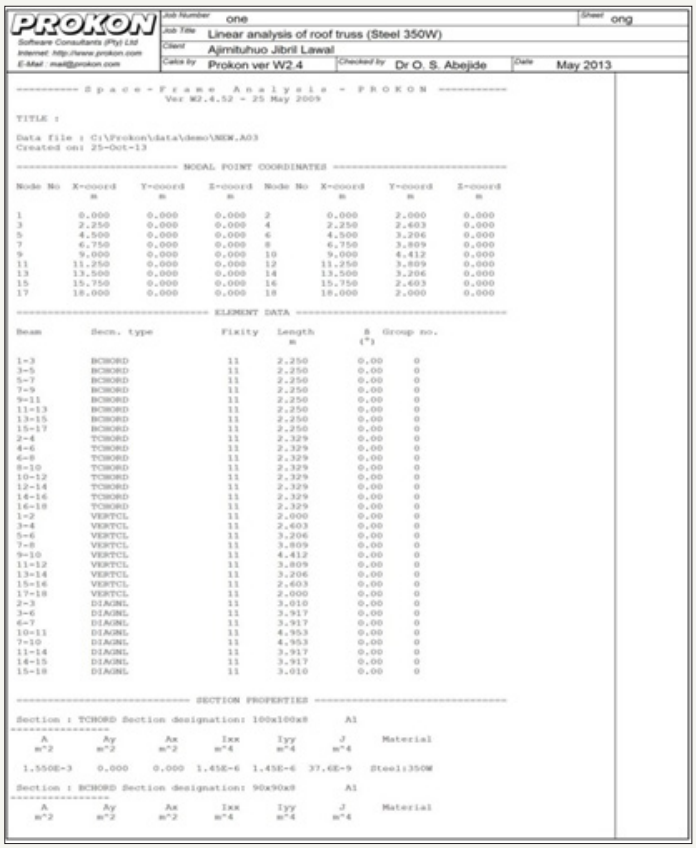

Figure 4:

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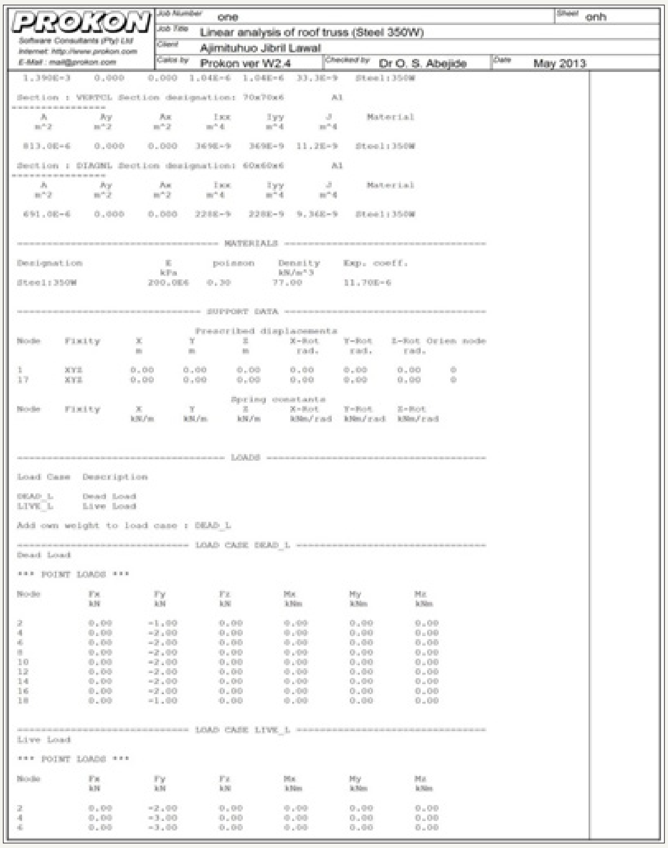
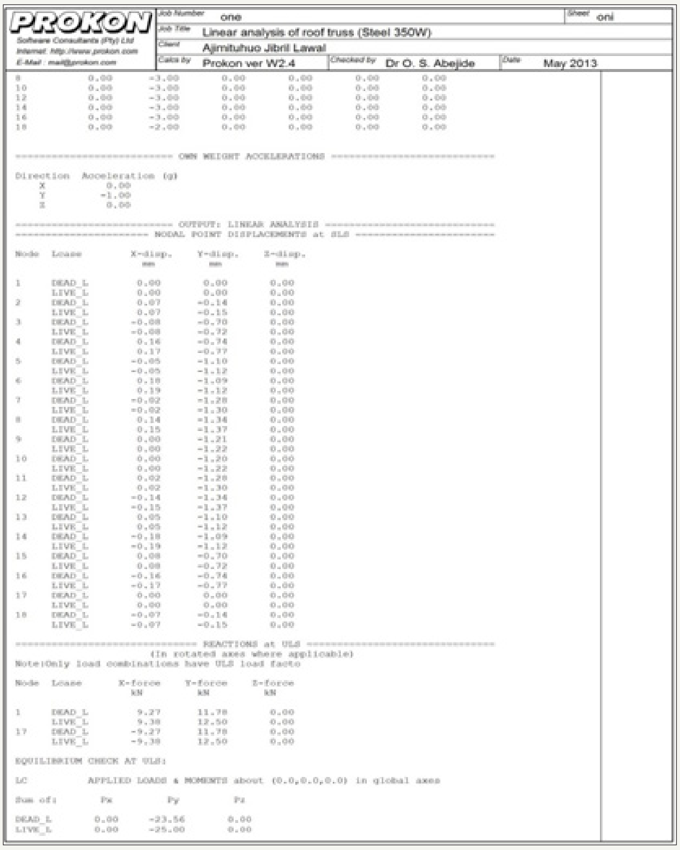


PROKON
Software Consultants (Pty) Ltd
Internet: http://www.prokon.com
E-Mail : mail@prokon.com

Job Number: one | Sheet: onh
Job Title: Linear analysis of roof truss (Steel 350W)
Client: Ajimituhuo Jibril Lawal
Calcs by: Prokon ver W2.4 | Checked by: Dr O. S. Abejide | Date: May 2013

```
 1.390E-3    0.000    0.000  1.04E-6  1.04E-6  33.3E-9   Steel:350W

Section : VERTCL Section designation: 70x70x6        A1
----------------
   A          Ay         Ax        Ixx       Iyy        J       Material
  m^2        m^2        m^2        m^4       m^4       m^4

 813.0E-6    0.000    0.000    369E-9    369E-9   11.2E-9   Steel:350W

Section : DIAGNL Section designation: 60x60x6        A1
----------------
   A          Ay         Ax        Ixx       Iyy        J       Material
  m^2        m^2        m^2        m^4       m^4       m^4

 691.0E-6    0.000    0.000    228E-9    228E-9   9.36E-9   Steel:350W


---------------------------------- MATERIALS ----------------------------------

Designation              E        poisson    Density    Exp. coeff.
                        kPa                  kN/m^3
Steel:350W           200.0E6    0.30        77.00      11.70E-6


------------------------------- SUPPORT DATA ----------------------------------

                               Prescribed displacements
Node    Fixity      X        Y        Z        X-Rot    Y-Rot   Z-Rot Orien node
                    m        m        m         rad.     rad.    rad.

1       XYZ       0.00     0.00     0.00     0.00     0.00     0.00      0
17      XYZ       0.00     0.00     0.00     0.00     0.00     0.00      0

                                 Spring constants
Node    Fixity      X        Y        Z        X-Rot    Y-Rot    Z-Rot
                  kN/m     kN/m     kN/m     kNm/rad  kNm/rad  kNm/rad



------------------------------------ LOADS ------------------------------------

Load Case  Description

DEAD_L     Dead Load
LIVE_L     Live Load

Add own weight to load case : DEAD_L

----------------------------- LOAD CASE DEAD_L --------------------------------
Dead Load

*** POINT LOADS ***

Node         Fx          Fy          Fz          Mx          My          Mz
             kN          kN          kN          kNm         kNm         kNm

2           0.00       -1.00        0.00        0.00        0.00        0.00
4           0.00       -2.00        0.00        0.00        0.00        0.00
6           0.00       -2.00        0.00        0.00        0.00        0.00
8           0.00       -2.00        0.00        0.00        0.00        0.00
10          0.00       -2.00        0.00        0.00        0.00        0.00
12          0.00       -2.00        0.00        0.00        0.00        0.00
14          0.00       -2.00        0.00        0.00        0.00        0.00
16          0.00       -2.00        0.00        0.00        0.00        0.00
18          0.00       -1.00        0.00        0.00        0.00        0.00


----------------------------- LOAD CASE LIVE_L --------------------------------
Live Load

*** POINT LOADS ***

Node         Fx          Fy          Fz          Mx          My          Mz
             kN          kN          kN          kNm         kNm         kNm

2           0.00       -2.00        0.00        0.00        0.00        0.00
4           0.00       -3.00        0.00        0.00        0.00        0.00
6           0.00       -3.00        0.00        0.00        0.00        0.00
```

Figure 5:



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```
8           0.00       -3.00        0.00        0.00        0.00        0.00
10          0.00       -3.00        0.00        0.00        0.00        0.00
12          0.00       -3.00        0.00        0.00        0.00        0.00
14          0.00       -3.00        0.00        0.00        0.00        0.00
16          0.00       -3.00        0.00        0.00        0.00        0.00
18          0.00       -2.00        0.00        0.00        0.00        0.00


-------------------------- OWN WEIGHT ACCELERATIONS ---------------------------

Direction  Acceleration (g)
    X          0.00
    Y         -1.00
    Z          0.00

-------------------------- OUTPUT: LINEAR ANALYSIS ----------------------------
---------------------- NODAL POINT DISPLACEMENTS at SLS -----------------------

Node  Lcase        X-disp.    Y-disp.    Z-disp.
                     mm         mm         mm

1     DEAD_L        0.00       0.00       0.00
      LIVE_L        0.00       0.00       0.00
2     DEAD_L        0.07      -0.14       0.00
      LIVE_L        0.07      -0.15       0.00
3     DEAD_L       -0.08      -0.70       0.00
      LIVE_L       -0.08      -0.72       0.00
4     DEAD_L        0.16      -0.74       0.00
      LIVE_L        0.17      -0.77       0.00
5     DEAD_L       -0.05      -1.10       0.00
      LIVE_L       -0.05      -1.12       0.00
6     DEAD_L        0.18      -1.09       0.00
      LIVE_L        0.19      -1.12       0.00
7     DEAD_L       -0.02      -1.28       0.00
      LIVE_L       -0.02      -1.30       0.00
8     DEAD_L        0.14      -1.34       0.00
      LIVE_L        0.15      -1.37       0.00
9     DEAD_L        0.00      -1.21       0.00
      LIVE_L        0.00      -1.22       0.00
10    DEAD_L        0.00      -1.20       0.00
      LIVE_L        0.00      -1.22       0.00
11    DEAD_L        0.02      -1.28       0.00
      LIVE_L        0.02      -1.30       0.00
12    DEAD_L       -0.14      -1.34       0.00
      LIVE_L       -0.15      -1.37       0.00
13    DEAD_L        0.05      -1.10       0.00
      LIVE_L        0.05      -1.12       0.00
14    DEAD_L       -0.18      -1.09       0.00
      LIVE_L       -0.19      -1.12       0.00
15    DEAD_L        0.08      -0.70       0.00
      LIVE_L        0.08      -0.72       0.00
16    DEAD_L       -0.16      -0.74       0.00
      LIVE_L       -0.17      -0.77       0.00
17    DEAD_L        0.00       0.00       0.00
      LIVE_L        0.00       0.00       0.00
18    DEAD_L       -0.07      -0.14       0.00
      LIVE_L       -0.07      -0.15       0.00

------------------------------ REACTIONS at ULS -------------------------------
                         (In rotated axes where applicable)
Note:Only load combinations have ULS load facto

Node  Lcase       X-force    Y-force    Z-force
                    kN         kN         kN

1     DEAD_L        9.27      11.78       0.00
      LIVE_L        9.38      12.50       0.00
17    DEAD_L       -9.27      11.78       0.00
      LIVE_L       -9.38      12.50       0.00

EQUILIBRIUM CHECK AT ULS:

LC          APPLIED LOADS & MOMENTS about (0.0,0.0,0.0) in global axes

Sum of:       Fx         Fy         Fz

DEAD_L       0.00     -23.56       0.00
LIVE_L       0.00     -25.00       0.00
```

Figure 6:

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LC REACTIONS & REACTION MOMENTS about (0.0,0.0,0.0) in global axes

Sum of:	Rx	Ry	Rz
DEAD_L	-0.00	23.56	0.00
LIVE_L	-0.00	25.00	0.00

========== BEAM ELEMENT END FORCES IN LOCAL ELEMENT AXES at ULS ==========

Elem	Lcase	Axial kN	Y-Shear kN	X-Shear kN	Axial kN	Y-Shear kN	X-Shear kN
1-3	DEAD_L	9.27	0.12	0.00	-9.27	0.12	0.00
	LIVE_L	9.38	0.00	0.00	-9.38	-0.00	0.00
3-5	DEAD_L	-3.20	0.12	0.00	3.20	0.12	0.00
	LIVE_L	-3.26	-0.00	0.00	3.26	-0.00	0.00
5-7	DEAD_L	-3.20	0.12	0.00	3.20	0.12	0.00
	LIVE_L	-3.26	-0.00	0.00	3.26	-0.00	0.00
7-9	DEAD_L	-2.88	0.12	0.00	2.88	0.12	0.00
	LIVE_L	-2.86	-0.00	0.00	2.86	-0.00	0.00
9-11	DEAD_L	-2.88	0.12	0.00	2.88	0.12	0.00
	LIVE_L	-2.86	-0.00	0.00	2.86	-0.00	0.00
11-13	DEAD_L	-3.20	0.12	0.00	3.20	0.12	0.00
	LIVE_L	-3.26	-0.00	0.00	3.26	-0.00	0.00
13-15	DEAD_L	-3.20	0.12	0.00	3.20	0.12	0.00
	LIVE_L	-3.26	-0.00	0.00	3.26	-0.00	0.00
15-17	DEAD_L	9.27	0.12	0.00	-9.27	0.12	0.00
	LIVE_L	9.38	-0.00	0.00	-9.38	0.00	0.00
2-4	DEAD_L	9.27	0.13	0.00	-9.20	0.13	0.00
	LIVE_L	9.40	0.00	0.00	-9.40	0.00	0.00
4-6	DEAD_L	9.27	0.13	0.00	-9.20	0.13	0.00
	LIVE_L	9.40	0.00	0.00	-9.40	0.00	0.00
6-8	DEAD_L	13.67	0.13	0.00	-13.60	0.13	0.00
	LIVE_L	13.76	0.00	0.00	-13.76	0.00	0.00
8-10	DEAD_L	13.67	0.13	0.00	-13.60	0.13	0.00
	LIVE_L	13.76	0.00	0.00	-13.76	0.00	0.00
10-12	DEAD_L	13.60	0.13	0.00	-13.67	0.13	0.00
	LIVE_L	13.76	-0.00	0.00	-13.76	0.00	0.00
12-14	DEAD_L	13.60	0.13	0.00	-13.67	0.13	0.00
	LIVE_L	13.76	-0.00	0.00	-13.76	0.00	0.00
14-16	DEAD_L	9.20	0.13	0.00	-9.27	0.13	0.00
	LIVE_L	9.40	0.00	0.00	-9.40	0.00	0.00
16-18	DEAD_L	9.20	0.13	0.00	-9.27	0.13	0.00
	LIVE_L	9.40	0.00	0.00	-9.40	0.00	0.00
1-2	DEAD_L	11.66	0.00	0.00	-11.54	-0.00	0.00
	LIVE_L	12.50	0.00	0.00	-12.50	-0.00	0.00
3-4	DEAD_L	2.44	0.00	0.00	-2.28	-0.00	0.00
	LIVE_L	3.00	0.00	0.00	-3.00	-0.00	0.00
5-6	DEAD_L	-0.24	0.00	0.00	0.44	-0.00	0.00
	LIVE_L	0.00	0.00	0.00	-0.00	-0.00	0.00
7-8	DEAD_L	2.52	0.00	0.00	-2.28	-0.00	0.00
	LIVE_L	3.00	0.00	0.00	-3.00	-0.00	0.00
9-10	DEAD_L	-0.24	0.00	0.00	0.52	0.00	0.00
	LIVE_L	0.00	0.00	0.00	-0.00	0.00	0.00
11-12	DEAD_L	2.52	-0.00	0.00	-2.28	0.00	0.00
	LIVE_L	3.00	-0.00	0.00	-3.00	0.00	0.00
13-14	DEAD_L	-0.24	-0.00	0.00	0.44	0.00	0.00
	LIVE_L	0.00	-0.00	0.00	-0.00	0.00	0.00
15-16	DEAD_L	2.44	-0.00	0.00	-2.28	0.00	0.00
	LIVE_L	3.00	-0.00	0.00	-3.00	0.00	0.00
17-18	DEAD_L	11.66	0.00	0.00	-11.54	0.00	0.00
	LIVE_L	12.50	0.00	0.00	-12.50	0.00	0.00
2-3	DEAD_L	-11.98	0.06	0.00	11.88	0.06	0.00
	LIVE_L	-12.14	0.00	0.00	12.14	-0.00	0.00
3-4	DEAD_L	6.27	0.06	0.00	-6.10	0.06	0.00
	LIVE_L	6.19	0.00	0.00	-6.19	-0.00	0.00
4-7	DEAD_L	-1.30	0.06	0.00	1.13	0.06	0.00
	LIVE_L	-1.15	0.00	0.00	1.15	-0.00	0.00
10-11	DEAD_L	-2.36	0.06	0.00	2.13	0.06	0.00
	LIVE_L	-2.31	0.00	0.00	2.31	-0.00	0.00
7-10	DEAD_L	-2.13	0.06	0.00	2.36	0.06	0.00
	LIVE_L	-2.31	0.00	0.00	2.31	-0.00	0.00
11-14	DEAD_L	-1.13	0.06	0.00	1.30	0.06	0.00
	LIVE_L	-1.15	0.00	0.00	1.15	0.00	0.00
14-15	DEAD_L	6.10	0.06	0.00	-6.27	0.06	0.00
	LIVE_L	6.19	-0.00	0.00	-6.19	0.00	0.00
15-18	DEAD_L	-11.88	0.06	0.00	11.98	0.06	0.00

Figure 7:

PROKON
Software Consultants (Pty) Ltd
Internet: http://www.prokon.com
E-Mail : mail@prokon.com

Job Number: one | Sheet: onk
Job Title: Linear analysis of roof truss (Steel 350W)
Client: Ajimituhuo Jibril Lawal
Calcs by: Prokon ver W2.4 | Checked by: Dr O. S. Abejide | Date: May 2013

LIVE_L	-12.14	-0.00	0.00	12.14	0.00	0.00

========== STATISTICAL DATA ==========

Weights of beam elements: (Added to load case DEAD_L)

Section Designation		Total (kN)	Weight (kg)
TCHORD 100x100x8	A1	2.224	226.7
BCHORD 90x90x8	A1	1.927	196.4
VERTCL 70x70x6	A1	1.731	176.4
DIAGNL 60x60x6	A1	1.681	171.4
		7.562	770.9

Own weight of structure = 7.56 kN

No. of real numbers in Stiffness matrix = 0 (0 bytes)
Time used to analyse = 0: 0:0.016 seconds
Total number of : Nodes = 18
Beam Elements = 33
Cable Elements = 0
Shell Elements = 0
Supports = 2
Section Properties = 4
Load Cases = 2
Load Combinations = 0

========== END OF OUTPUT ==========

Figure 8:

How to cite this article: Ajimituhuo J, Abejide O. Effectiveness and Shape Design of CFRP Structural Sections in Roof Trusses . 5(5). RDMS.000624.2018.
DOI: 10.31031/RDMS.2018.05.000624

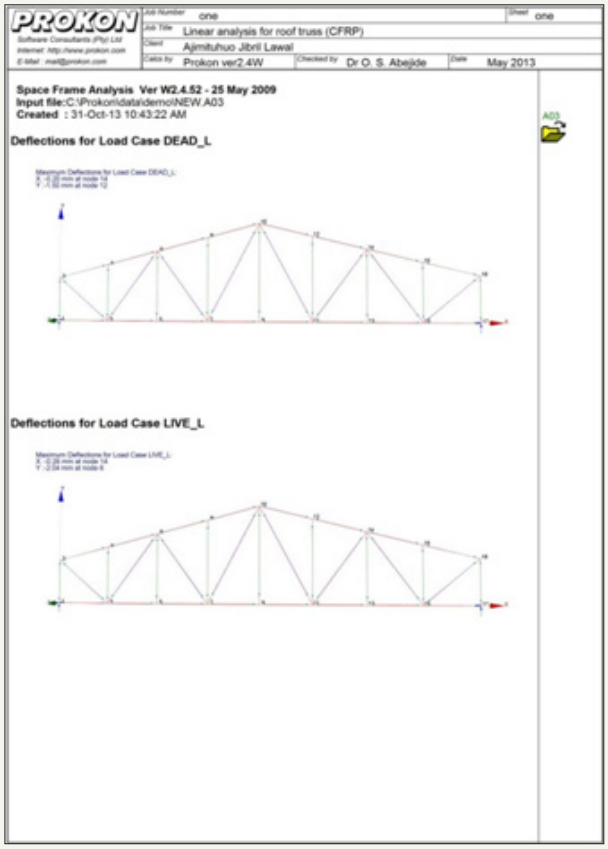


Figure 9:

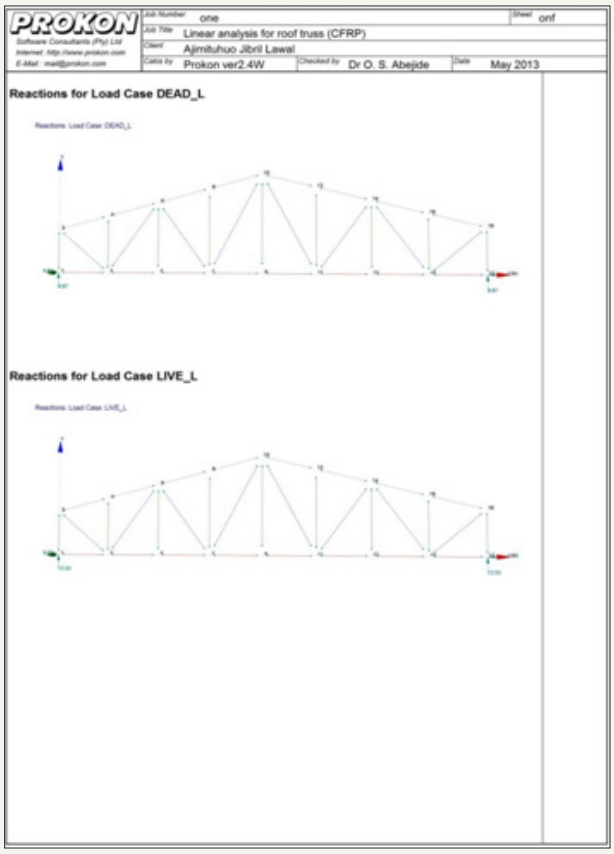


Figure 10:

How to cite this article: Ajimituhuo J, Abejide O. Effectiveness and Shape Design of CFRP Structural Sections in Roof Trusses . 5(5). RDMS.000624.2018.
DOI: 10.31031/RDMS.2018.05.000624

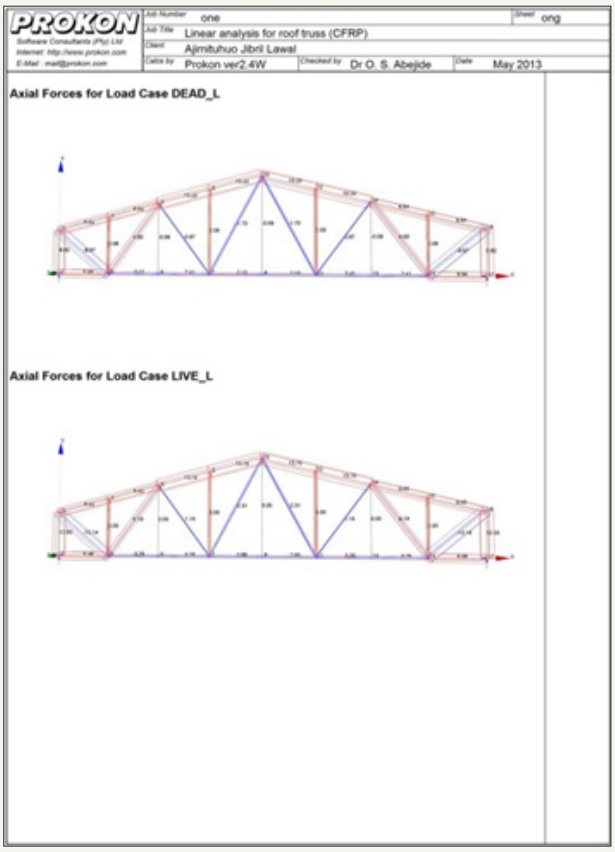


Figure 11:

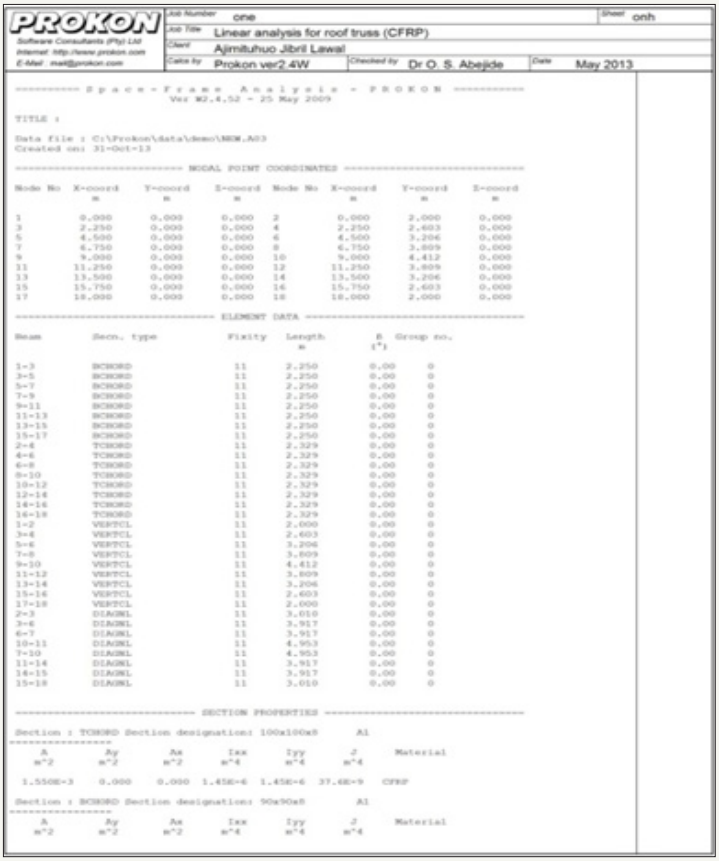
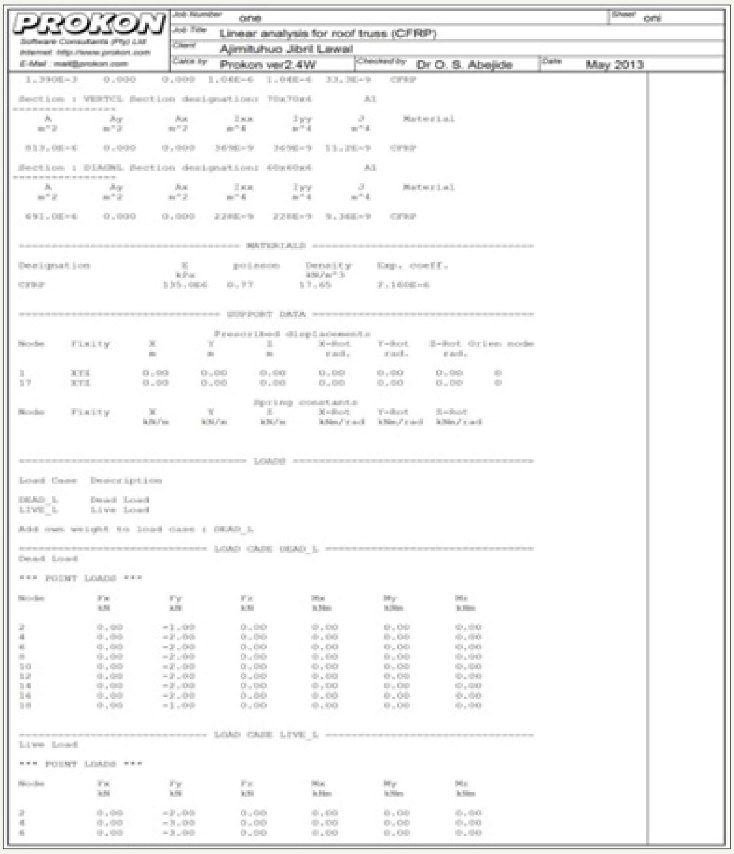


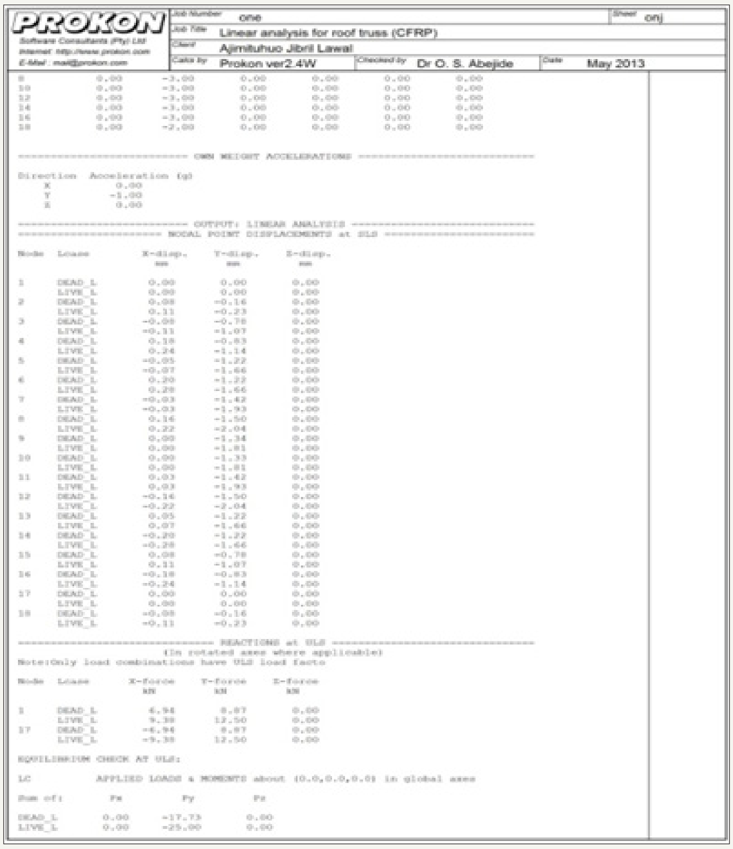
Figure 12:

How to cite this article: Ajimituhuo J, Abejide O. Effectiveness and Shape Design of CFRP Structural Sections in Roof Trusses . 5(5). RDMS.000624.2018.
DOI: 10.31031/RDMS.2018.05.000624



```
PROKON   Job Number  one                                        Sheet  onj
Software Consultants (Pty) Ltd
Internet: http://www.prokon.com
E-Mail : mail@prokon.com
Job Title  Linear analysis for roof truss (CFRP)
Client     Ajimituhuo Jibril Lawal
Calcs by   Prokon ver2.4W    Checked by  Dr O. S. Abejide    Date  May 2013

 1.390E-3    0.000    0.000  1.04E-6  1.04E-6  33.3E-9   CFRP

Section : VERTCL Section designation: 70x70x6        A1
-----------------
    A          Ay         Ax        Ixx       Iyy        J       Material
   m^2        m^2        m^2       m^4       m^4       m^4

 813.0E-6    0.000      0.000     369E-9    369E-9   11.2E-9   CFRP

Section : DIAGNL Section designation: 60x60x6        A1
-----------------
    A          Ay         Ax        Ixx       Iyy        J       Material
   m^2        m^2        m^2       m^4       m^4       m^4

 691.0E-6    0.000      0.000     228E-9    228E-9   9.36E-9   CFRP

-------------------------------------- MATERIALS --------------------------------------

Designation                 E        poisson     Density      Exp. coeff.
                           kPa                   kN/m^3
CFRP                    135.0E6    0.77         17.65        2.160E-6

---------------------------------- SUPPORT DATA ----------------------------------

                               Prescribed displacements
Node    Fixity       X         Y         Z       X-Rot     Y-Rot    Z-Rot  Orien node
                     m         m         m       rad.      rad.     rad.

1       XYZ        0.00      0.00      0.00      0.00      0.00     0.00      0
17      XYZ        0.00      0.00      0.00      0.00      0.00     0.00      0

                                  Spring constants
Node    Fixity       X         Y         Z       X-Rot     Y-Rot    Z-Rot
                    kN/m      kN/m      kN/m    kNm/rad   kNm/rad  kNm/rad


--------------------------------------- LOADS ---------------------------------------

Load Case   Description

DEAD_L      Dead Load
LIVE_L      Live Load

Add own weight to load case : DEAD_L

--------------------------------- LOAD CASE DEAD_L ---------------------------------
Dead Load

*** POINT LOADS ***

Node          Fx          Fy          Fz          Mx          My          Mz
              kN          kN          kN          kNm         kNm         kNm

2            0.00       -1.00        0.00        0.00        0.00        0.00
4            0.00       -2.00        0.00        0.00        0.00        0.00
6            0.00       -2.00        0.00        0.00        0.00        0.00
8            0.00       -2.00        0.00        0.00        0.00        0.00
10           0.00       -2.00        0.00        0.00        0.00        0.00
12           0.00       -2.00        0.00        0.00        0.00        0.00
14           0.00       -2.00        0.00        0.00        0.00        0.00
16           0.00       -2.00        0.00        0.00        0.00        0.00
18           0.00       -1.00        0.00        0.00        0.00        0.00

--------------------------------- LOAD CASE LIVE_L ---------------------------------
Live Load

*** POINT LOADS ***

Node          Fx          Fy          Fz          Mx          My          Mz
              kN          kN          kN          kNm         kNm         kNm

2            0.00       -2.00        0.00        0.00        0.00        0.00
4            0.00       -3.00        0.00        0.00        0.00        0.00
6            0.00       -3.00        0.00        0.00        0.00        0.00
```

Figure 13:



```
PROKON   Job Number  one                                        Sheet  onj
Software Consultants (Pty) Ltd
Internet: http://www.prokon.com
E-Mail : mail@prokon.com
Job Title  Linear analysis for roof truss (CFRP)
Client     Ajimituhuo Jibril Lawal
Calcs by   Prokon ver2.4W    Checked by  Dr O. S. Abejide    Date  May 2013

8            0.00       -3.00        0.00        0.00        0.00        0.00
10           0.00       -3.00        0.00        0.00        0.00        0.00
12           0.00       -3.00        0.00        0.00        0.00        0.00
14           0.00       -3.00        0.00        0.00        0.00        0.00
16           0.00       -3.00        0.00        0.00        0.00        0.00
18           0.00       -2.00        0.00        0.00        0.00        0.00

--------------------------- OWN WEIGHT ACCELERATIONS ---------------------------

Direction  Acceleration (g)
    X          0.00
    Y         -1.00
    Z          0.00

--------------------------- OUTPUT: LINEAR ANALYSIS ---------------------------
---------------------- NODAL POINT DISPLACEMENTS at SLS ----------------------

Node   Lcase          X-disp.     Y-disp.     Z-disp.
                        mm          mm          mm

1      DEAD_L         0.00        0.00        0.00
       LIVE_L         0.00        0.00        0.00
2      DEAD_L         0.08       -0.16        0.00
       LIVE_L         0.11       -0.23        0.00
3      DEAD_L        -0.08       -0.78        0.00
       LIVE_L        -0.11       -1.07        0.00
4      DEAD_L         0.18       -0.83        0.00
       LIVE_L         0.24       -1.14        0.00
5      DEAD_L        -0.05       -1.22        0.00
       LIVE_L        -0.07       -1.66        0.00
6      DEAD_L         0.20       -1.22        0.00
       LIVE_L         0.28       -1.66        0.00
7      DEAD_L        -0.03       -1.42        0.00
       LIVE_L        -0.03       -1.93        0.00
8      DEAD_L         0.16       -1.50        0.00
       LIVE_L         0.22       -2.04        0.00
9      DEAD_L         0.00       -1.34        0.00
       LIVE_L         0.00       -1.81        0.00
10     DEAD_L         0.00       -1.33        0.00
       LIVE_L         0.00       -1.81        0.00
11     DEAD_L         0.03       -1.42        0.00
       LIVE_L         0.03       -1.93        0.00
12     DEAD_L        -0.16       -1.50        0.00
       LIVE_L        -0.22       -2.04        0.00
13     DEAD_L         0.05       -1.22        0.00
       LIVE_L         0.07       -1.66        0.00
14     DEAD_L        -0.20       -1.22        0.00
       LIVE_L        -0.28       -1.66        0.00
15     DEAD_L         0.08       -0.78        0.00
       LIVE_L         0.11       -1.07        0.00
16     DEAD_L        -0.18       -0.83        0.00
       LIVE_L        -0.24       -1.14        0.00
17     DEAD_L         0.00        0.00        0.00
       LIVE_L         0.00        0.00        0.00
18     DEAD_L        -0.08       -0.16        0.00
       LIVE_L        -0.11       -0.23        0.00

-------------------------------- REACTIONS at ULS --------------------------------
                        (In rotated axes where applicable)
Note:Only load combinations have ULS load facto

Node   Lcase         X-force     Y-force     Z-force
                       kN          kN          kN

1      DEAD_L         6.94        8.87        0.00
       LIVE_L         9.38       12.50        0.00
17     DEAD_L        -6.94        8.87        0.00
       LIVE_L        -9.38       12.50        0.00

EQUILIBRIUM CHECK AT ULS:

LC          APPLIED LOADS & MOMENTS about (0.0,0.0,0.0) in global axes

Sum of:         Fx          Fy          Fz

DEAD_L         0.00      -17.73        0.00
LIVE_L         0.00      -25.00        0.00
```

Figure 14:

How to cite this article: Ajimituhuo J, Abejide O. Effectiveness and Shape Design of CFRP Structural Sections in Roof Trusses . 5(5). RDMS.000624.2018.
DOI: 10.31031/RDMS.2018.05.000624

PROKON
Software Consultants (Pty) Ltd
Internet: http://www.prokon.com
E-Mail : mail@prokon.com

Job Number: one | Sheet: onk
Job Title: Linear analysis for roof truss (CFRP)
Client: Ajimituhuo Jibril Lawal
Calcs by: Prokon ver2.4W | Checked by: Dr O. S. Abejide | Date: May 2013

LC REACTIONS & REACTION MOMENTS about (0.0,0.0,0.0) in global axes

Sum of:	Rx	Ry	Rz
DEAD_L	0.00	17.73	0.00
LIVE_L	-0.00	25.00	0.00

========== BEAM ELEMENT END FORCES IN LOCAL ELEMENT AXES at ULS ==========

Elem	Loads	Axial kN	Y-Shear kN	X-Shear kN	Axial kN	Y-Shear kN	X-Shear kN
1-3	DEAD_L	6.94	0.03	0.00	-6.94	0.03	0.00
	LIVE_L	9.38	0.00	0.00	-9.38	-0.00	0.00
3-5	DEAD_L	-2.41	0.03	0.00	2.41	0.03	0.00
	LIVE_L	-3.26	-0.00	0.00	3.26	-0.00	0.00
5-7	DEAD_L	-2.41	0.03	0.00	2.41	0.03	0.00
	LIVE_L	-3.26	-0.00	0.00	3.26	-0.00	0.00
7-9	DEAD_L	-2.13	0.03	0.00	2.13	0.03	0.00
	LIVE_L	-2.86	-0.00	0.00	2.86	-0.00	0.00
9-11	DEAD_L	-2.13	0.03	0.00	2.13	0.03	0.00
	LIVE_L	-2.86	-0.00	0.00	2.86	-0.00	0.00
11-13	DEAD_L	-2.41	0.03	0.00	2.41	0.03	0.00
	LIVE_L	-3.26	-0.00	0.00	3.26	-0.00	0.00
13-15	DEAD_L	-2.41	0.03	0.00	2.41	0.03	0.00
	LIVE_L	-3.26	-0.00	0.00	3.26	-0.00	0.00
15-17	DEAD_L	6.94	0.03	0.00	-6.94	0.03	0.00
	LIVE_L	9.38	-0.00	0.00	-9.38	0.00	0.00
2-4	DEAD_L	6.95	0.03	0.00	-6.94	0.03	0.00
	LIVE_L	9.40	0.00	0.00	-9.40	0.00	0.00
4-6	DEAD_L	6.95	0.03	0.00	-6.94	0.03	0.00
	LIVE_L	9.40	0.00	0.00	-9.40	-0.00	0.00
6-8	DEAD_L	10.20	0.03	0.00	-10.19	0.03	0.00
	LIVE_L	13.76	0.00	0.00	-13.76	0.00	0.00
8-10	DEAD_L	10.20	0.03	0.00	-10.19	0.03	0.00
	LIVE_L	13.76	-0.00	0.00	-13.76	0.00	0.00
10-12	DEAD_L	10.19	0.03	0.00	-10.20	0.03	0.00
	LIVE_L	13.76	-0.00	0.00	-13.76	-0.00	0.00
12-14	DEAD_L	10.19	0.03	0.00	-10.20	0.03	0.00
	LIVE_L	13.76	0.00	0.00	-13.76	0.00	0.00
14-16	DEAD_L	6.94	0.03	0.00	-6.95	0.03	0.00
	LIVE_L	9.40	-0.00	0.00	-9.40	-0.00	0.00
16-18	DEAD_L	6.94	0.03	0.00	-6.95	0.03	0.00
	LIVE_L	9.40	0.00	0.00	-9.40	0.00	0.00
1-2	DEAD_L	8.84	0.00	0.00	-8.81	-0.00	0.00
	LIVE_L	12.50	0.00	0.00	-12.50	-0.00	0.00
3-4	DEAD_L	2.10	0.00	0.00	-2.06	-0.00	0.00
	LIVE_L	3.00	0.00	0.00	-3.00	-0.00	0.00
5-6	DEAD_L	-0.06	0.00	0.00	0.10	-0.00	0.00
	LIVE_L	0.00	0.00	0.00	-0.00	-0.00	0.00
7-8	DEAD_L	2.12	0.00	0.00	-2.06	-0.00	0.00
	LIVE_L	3.00	0.00	0.00	-3.00	-0.00	0.00
9-10	DEAD_L	-0.06	0.00	0.00	0.12	0.00	0.00
	LIVE_L	0.00	0.00	0.00	-0.00	0.00	0.00
11-12	DEAD_L	2.12	-0.00	0.00	-2.06	0.00	0.00
	LIVE_L	3.00	-0.00	0.00	-3.00	0.00	0.00
13-14	DEAD_L	-0.06	-0.00	0.00	0.10	0.00	0.00
	LIVE_L	0.00	-0.00	0.00	-0.00	0.00	0.00
15-16	DEAD_L	2.10	-0.00	0.00	-2.06	0.00	0.00
	LIVE_L	3.00	-0.00	0.00	-3.00	0.00	0.00
17-18	DEAD_L	8.84	0.00	0.00	-8.81	0.00	0.00
	LIVE_L	12.50	0.00	0.00	-12.50	0.00	0.00
2-3	DEAD_L	-8.99	0.01	0.00	8.96	0.01	0.00
	LIVE_L	-12.14	0.00	0.00	12.14	0.00	0.00
3-6	DEAD_L	4.62	0.01	0.00	-4.58	0.01	0.00
	LIVE_L	6.19	0.00	0.00	-6.19	0.00	0.00
6-7	DEAD_L	-0.89	0.01	0.00	0.85	0.01	0.00
	LIVE_L	-1.15	-0.00	0.00	1.15	0.00	0.00
10-11	DEAD_L	-1.73	0.01	0.00	1.68	0.01	0.00
	LIVE_L	-2.31	0.00	0.00	2.31	0.00	0.00
7-10	DEAD_L	-1.68	0.01	0.00	1.73	0.01	0.00
	LIVE_L	-2.31	0.00	0.00	2.31	-0.00	0.00
11-14	DEAD_L	-0.85	0.01	0.00	0.89	0.01	0.00
	LIVE_L	-1.15	0.00	0.00	1.15	0.00	0.00
14-15	DEAD_L	4.58	0.01	0.00	-4.62	0.01	0.00
	LIVE_L	6.19	-0.00	0.00	-6.19	0.00	0.00
15-18	DEAD_L	-8.96	0.01	0.00	8.99	0.01	0.00

Figure 15:

PROKON
Software Consultants (Pty) Ltd
Internet: http://www.prokon.com
E-Mail : mail@prokon.com

Job Number: one | Sheet: onl
Job Title: Linear analysis for roof truss (CFRP)
Client: Ajimituhuo Jibril Lawal
Calcs by: Prokon ver2.4W | Checked by: Dr O. S. Abejide | Date: May 2013

LIVE_L	-12.14	0.00	0.00	12.14	0.00	0.00

========== STATISTICAL DATA ==========

Weights of beam elements: (Added to load case DEAD_L)

Section Designation		Total (kN)	Weight (kg)
TCHORD 100x100x8	A1	0.510	52.0
BCHORD 90x90x8	A1	0.442	45.0
VERTCL 70x70x6	A1	0.397	40.4
DIAGNL 60x60x6	A1	0.385	39.3
		1.733	176.7

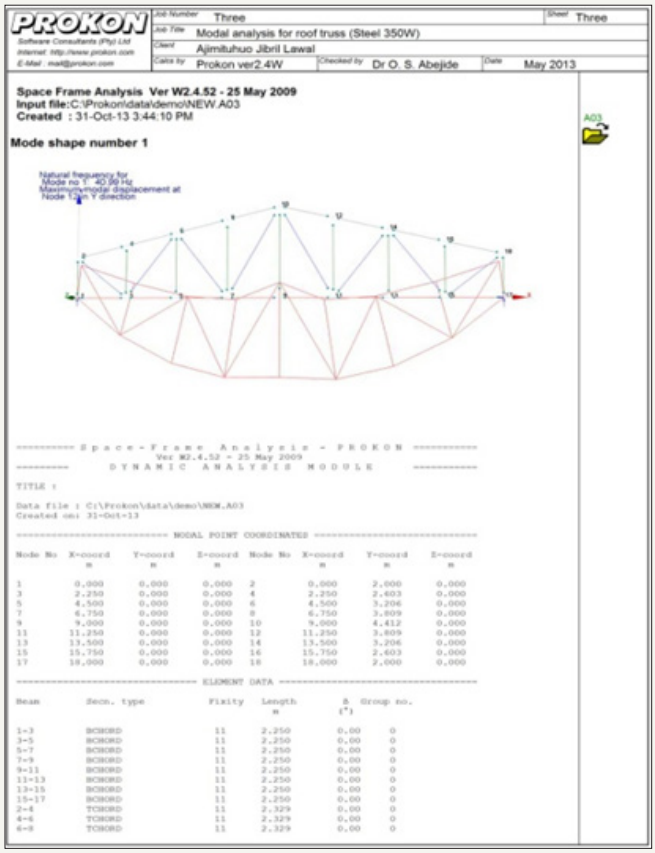
Own weight of structure = 1.73 kN

No. of real numbers in Stiffness matrix = 1746 (17460 bytes)
Time used to analyse = 0: 0:0.000 seconds
Total number of : Nodes = 18
Beam Elements = 33
Cable Elements = 0
Shell Elements = 0
Supports = 2
Section Properties = 4
Load Cases = 2
Load Combinations = 0

========== END OF OUTPUT ==========

Figure 16:

How to cite this article: Ajimituhuo J, Abejide O. Effectiveness and Shape Design of CFRP Structural Sections in Roof Trusses . 5(5). RDMS.000624.2018.
DOI: 10.31031/RDMS.2018.05.000624



PROKON

Software Consultants (Pty) Ltd
Internet: http://www.prokon.com
E-Mail : mail@prokon.com

Job Number: Three | Sheet: Three
Job Title: Modal analysis for roof truss (Steel 350W)
Client: Ajimituhuo Jibril Lawal
Calcs by: Prokon ver2.4W | Checked by: Dr O. S. Abejide | Date: May 2013

Space Frame Analysis Ver W2.4.52 - 25 May 2009
Input file: C:\Prokon\data\demo\NEW.A03
Created : 31-Oct-13 3:44:10 PM

Mode shape number 1

Natural frequency for
Mode no 1 : 40.99 Hz
Maximum modal displacement at
Node 13 in Y direction

A03

========== S p a c e - F r a m e A n a l y s i s - P R O K O N ==========
Ver W2.4.52 - 25 May 2009
D Y N A M I C A N A L Y S I S M O D U L E

TITLE :

Data file : C:\Prokon\data\demo\NEW.A03
Created on: 31-Oct-13

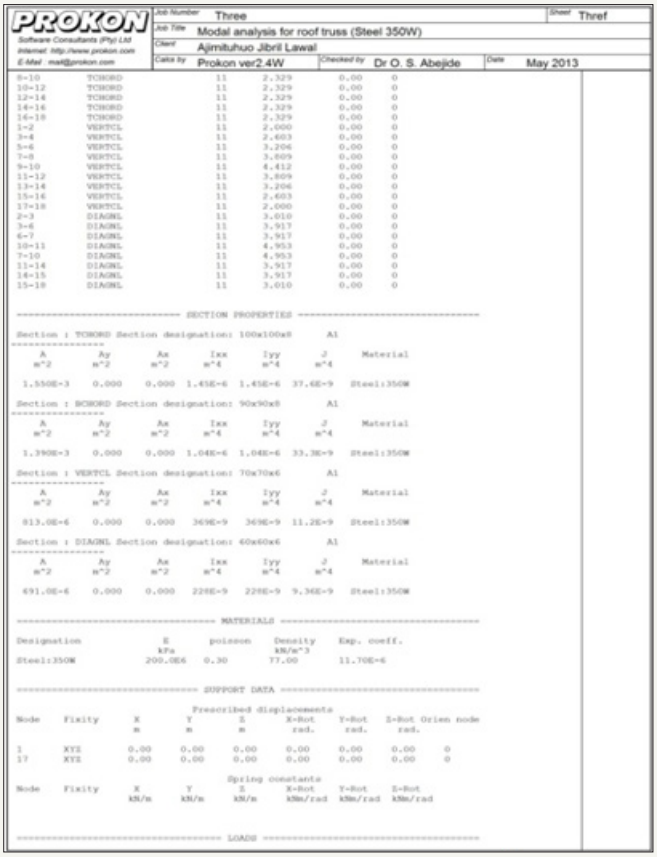
========== NODAL POINT COORDINATES ==========

Node No	X-coord m	Y-coord m	Z-coord m	Node No	X-coord m	Y-coord m	Z-coord m
1	0.000	0.000	0.000	2	0.000	2.000	0.000
3	2.250	0.000	0.000	4	2.250	2.603	0.000
5	4.500	0.000	0.000	6	4.500	3.206	0.000
7	6.750	0.000	0.000	8	6.750	3.809	0.000
9	9.000	0.000	0.000	10	9.000	4.412	0.000
11	11.250	0.000	0.000	12	11.250	3.809	0.000
13	13.500	0.000	0.000	14	13.500	3.206	0.000
15	15.750	0.000	0.000	16	15.750	2.603	0.000
17	18.000	0.000	0.000	18	18.000	2.000	0.000

========== ELEMENT DATA ==========

Beam	Secn. type	Fixity	Length m	β (°)	Group no.
1-3	BCHORD	11	2.250	0.00	0
3-5	BCHORD	11	2.250	0.00	0
5-7	BCHORD	11	2.250	0.00	0
7-9	BCHORD	11	2.250	0.00	0
9-11	BCHORD	11	2.250	0.00	0
11-13	BCHORD	11	2.250	0.00	0
13-15	BCHORD	11	2.250	0.00	0
15-17	BCHORD	11	2.250	0.00	0
2-4	TCHORD	11	2.329	0.00	0
4-6	TCHORD	11	2.329	0.00	0
6-8	TCHORD	11	2.329	0.00	0

Figure 17:



PROKON

Software Consultants (Pty) Ltd
Internet: http://www.prokon.com
E-Mail : mail@prokon.com

Job Number: Three | Sheet: Three
Job Title: Modal analysis for roof truss (Steel 350W)
Client: Ajimituhuo Jibril Lawal
Calcs by: Prokon ver2.4W | Checked by: Dr O. S. Abejide | Date: May 2013

8-10	TCHORD	11	2.329	0.00	0
10-12	TCHORD	11	2.329	0.00	0
12-14	TCHORD	11	2.329	0.00	0
14-16	TCHORD	11	2.329	0.00	0
16-18	TCHORD	11	2.329	0.00	0
1-2	VERTCL	11	2.000	0.00	0
3-4	VERTCL	11	2.603	0.00	0
5-6	VERTCL	11	3.206	0.00	0
7-8	VERTCL	11	3.809	0.00	0
9-10	VERTCL	11	4.412	0.00	0
11-12	VERTCL	11	3.809	0.00	0
13-14	VERTCL	11	3.206	0.00	0
15-16	VERTCL	11	2.603	0.00	0
17-18	VERTCL	11	2.000	0.00	0
2-3	DIAGNL	11	3.010	0.00	0
3-6	DIAGNL	11	3.917	0.00	0
6-7	DIAGNL	11	3.917	0.00	0
10-11	DIAGNL	11	4.953	0.00	0
7-10	DIAGNL	11	4.953	0.00	0
11-14	DIAGNL	11	3.917	0.00	0
14-15	DIAGNL	11	3.917	0.00	0
15-18	DIAGNL	11	3.010	0.00	0

========== SECTION PROPERTIES ==========

Section : TCHORD Section designation: 100x100x8 A1

A m^2	Ay m^2	Az m^2	Ixx m^4	Iyy m^4	J m^4	Material
1.550E-3	0.000	0.000	1.45E-6	1.45E-6	37.6E-9	Steel:350W

Section : BCHORD Section designation: 90x90x8 A1

A m^2	Ay m^2	Az m^2	Ixx m^4	Iyy m^4	J m^4	Material
1.390E-3	0.000	0.000	1.04E-6	1.04E-6	33.3E-9	Steel:350W

Section : VERTCL Section designation: 70x70x6 A1

A m^2	Ay m^2	Az m^2	Ixx m^4	Iyy m^4	J m^4	Material
813.0E-6	0.000	0.000	369E-9	369E-9	11.2E-9	Steel:350W

Section : DIAGNL Section designation: 60x60x6 A1

A m^2	Ay m^2	Az m^2	Ixx m^4	Iyy m^4	J m^4	Material
691.0E-6	0.000	0.000	228E-9	228E-9	9.36E-9	Steel:350W

========== MATERIALS ==========

Designation	E kPa	poisson	Density kN/m^3	Exp. coeff.
Steel:350W	200.0E6	0.30	77.00	11.70E-6

========== SUPPORT DATA ==========

Prescribed displacements

Node	Fixity	X m	Y m	Z m	X-Rot rad.	Y-Rot rad.	Z-Rot rad.	Orien node
1	XYZ	0.00	0.00	0.00	0.00	0.00	0.00	0
17	XYZ	0.00	0.00	0.00	0.00	0.00	0.00	0

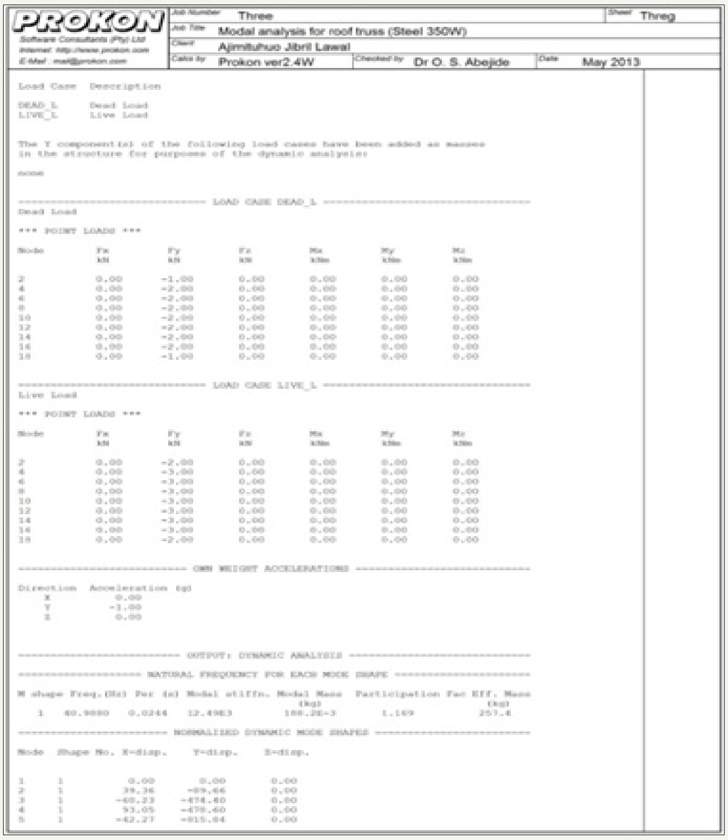
Spring constants

Node	Fixity	X kN/m	Y kN/m	Z kN/m	X-Rot kNm/rad	Y-Rot kNm/rad	Z-Rot kNm/rad

========== LOADS ==========

Figure 18:

How to cite this article: Ajimituhuo J, Abejide O. Effectiveness and Shape Design of CFRP Structural Sections in Roof Trusses . 5(5). RDMS.000624.2018.
DOI: 10.31031/RDMS.2018.05.000624



Job Number	Three	Sheet	Three
Job Title	Modal analysis for roof truss (Steel 350W)		
Client	Ajimituhuo Jibril Lawal		
Calcs by	Prokon ver2.4W	Checked by Dr O. S. Abejide	Date May 2013

Load Case Description

DEAD_L Dead Load
LIVE_L Live Load

The Y component(s) of the following load cases have been added as masses in the structure for purposes of the dynamic analysis:

none

------------------------------ LOAD CASE DEAD_L ------------------------------
Dead Load

*** POINT LOADS ***

Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
2	0.00	-1.00	0.00	0.00	0.00	0.00
4	0.00	-2.00	0.00	0.00	0.00	0.00
6	0.00	-2.00	0.00	0.00	0.00	0.00
8	0.00	-2.00	0.00	0.00	0.00	0.00
10	0.00	-2.00	0.00	0.00	0.00	0.00
12	0.00	-2.00	0.00	0.00	0.00	0.00
14	0.00	-2.00	0.00	0.00	0.00	0.00
16	0.00	-2.00	0.00	0.00	0.00	0.00
18	0.00	-1.00	0.00	0.00	0.00	0.00

------------------------------ LOAD CASE LIVE_L ------------------------------
Live Load

*** POINT LOADS ***

Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
2	0.00	-2.00	0.00	0.00	0.00	0.00
4	0.00	-3.00	0.00	0.00	0.00	0.00
6	0.00	-3.00	0.00	0.00	0.00	0.00
8	0.00	-3.00	0.00	0.00	0.00	0.00
10	0.00	-3.00	0.00	0.00	0.00	0.00
12	0.00	-3.00	0.00	0.00	0.00	0.00
14	0.00	-3.00	0.00	0.00	0.00	0.00
16	0.00	-3.00	0.00	0.00	0.00	0.00
18	0.00	-2.00	0.00	0.00	0.00	0.00

-------------------------- OWN WEIGHT ACCELERATIONS --------------------------

Direction	Acceleration (g)
X	0.00
Y	-1.00
Z	0.00

-------------------------- OUTPUT: DYNAMIC ANALYSIS --------------------------

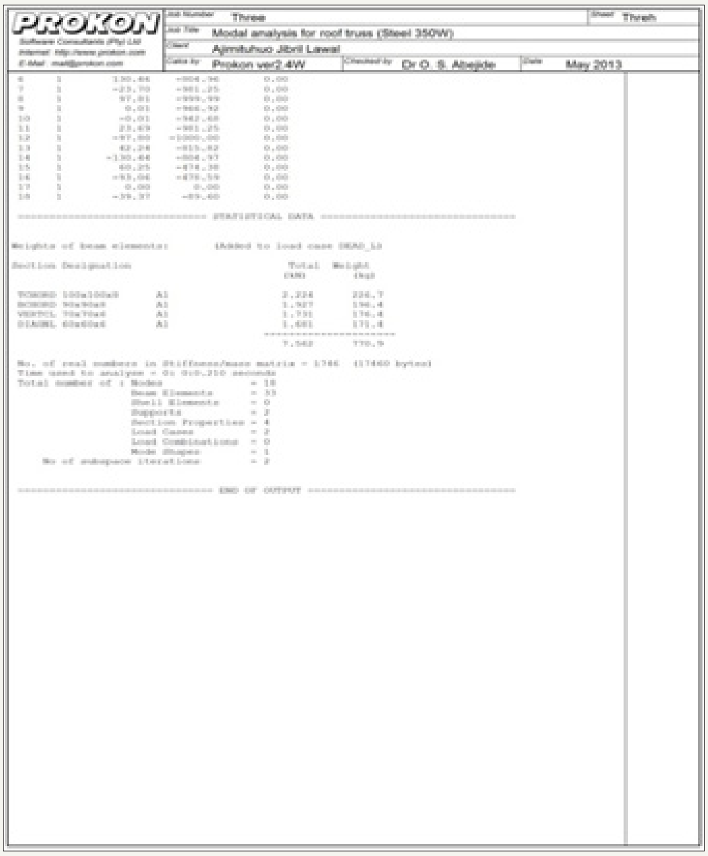
-------------------- NATURAL FREQUENCY FOR EACH MODE SHAPE --------------------

M shape	Freq.(Hz)	Per (s)	Modal stiffn.	Modal Mass (kg)	Participation Fac	Eff. Mass (kg)
1	40.9880	0.0244	12.49E3	188.2E-3	1.169	257.4

----------------------- NORMALIZED DYNAMIC MODE SHAPES -----------------------

Node	Shape No.	X-disp.	Y-disp.	Z-disp.
1	1	0.00	0.00	0.00
2	1	39.36	-89.66	0.00
3	1	-60.23	-474.40	0.00
4	1	53.05	-478.60	0.00
5	1	-42.27	-815.84	0.00

Figure 19:



Job Number	Three	Sheet	Threh
Job Title	Modal analysis for roof truss (Steel 350W)		
Client	Ajimituhuo Jibril Lawal		
Calcs by	Prokon ver2.4W	Checked by Dr O. S. Abejide	Date May 2013

Node	Shape No.	X-disp.	Y-disp.	Z-disp.
6	1	130.46	-804.96	0.00
7	1	-23.70	-981.25	0.00
8	1	97.81	-999.99	0.00
9	1	0.01	-966.92	0.00
10	1	-0.01	-942.68	0.00
11	1	23.69	-981.25	0.00
12	1	-97.80	-1000.00	0.00
13	1	42.24	-815.62	0.00
14	1	-130.46	-804.97	0.00
15	1	60.25	-474.38	0.00
16	1	-53.04	-478.59	0.00
17	1	0.00	0.00	0.00
18	1	-39.37	-89.60	0.00

------------------------------ STATISTICAL DATA ------------------------------

Weights of beam elements: (Added to load case DEAD_L)

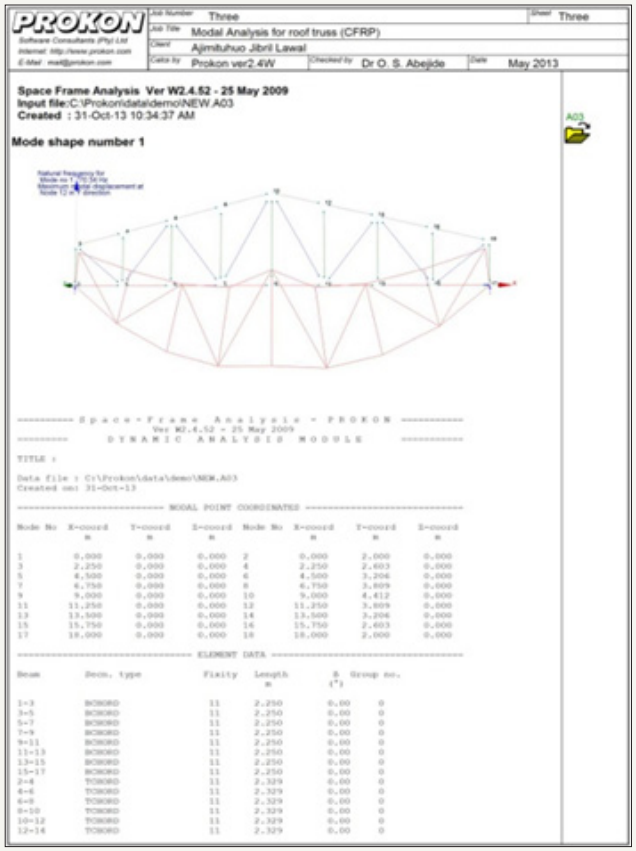
Section Designation		Total (kN)	Weight (kg)
TCHORD 100x100x8	A1	2.224	226.7
BCHORD 90x90x8	A1	1.927	196.4
VERTCL 70x70x6	A1	1.731	176.4
DIAGNL 60x60x6	A1	1.681	171.4
		7.562	770.9

No. of real numbers in Stiffness/mass matrix = 1746 (17460 bytes)
Time used to analyse = 0: 0:0.250 seconds
Total number of : Nodes = 18
Beam Elements = 33
Shell Elements = 0
Supports = 2
Section Properties = 4
Load Cases = 2
Load Combinations = 0
Mode Shapes = 1
No of subspace iterations = 2

------------------------------ END OF OUTPUT ------------------------------

Figure 20:

How to cite this article: Ajimituhuo J, Abejide O. Effectiveness and Shape Design of CFRP Structural Sections in Roof Trusses . 5(5). RDMS.000624.2018.
DOI: 10.31031/RDMS.2018.05.000624



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Software Consultants (Pty) Ltd
Internet: http://www.prokon.com
E-Mail: mail@prokon.com

Job Number	Three	Sheet	Three
Job Title	Modal Analysis for roof truss (CFRP)		
Client	Ajimituhuo Jibril Lawal		
Calcs by	Prokon ver2.4W	Checked by: Dr O. S. Abejide	Date: May 2013

Space Frame Analysis Ver W2.4.52 - 25 May 2009
Input file:C:\Prokon\data\demo\NEW.A03
Created : 31-Oct-13 10:34:37 AM

Mode shape number 1

A03

---------- Space-Frame Analysis - PROKON ----------
Ver W2.4.52 - 25 May 2009
--------- DYNAMIC ANALYSIS MODULE ----------

TITLE :

Data file : C:\Prokon\data\demo\NEW.A03
Created on: 31-Oct-13

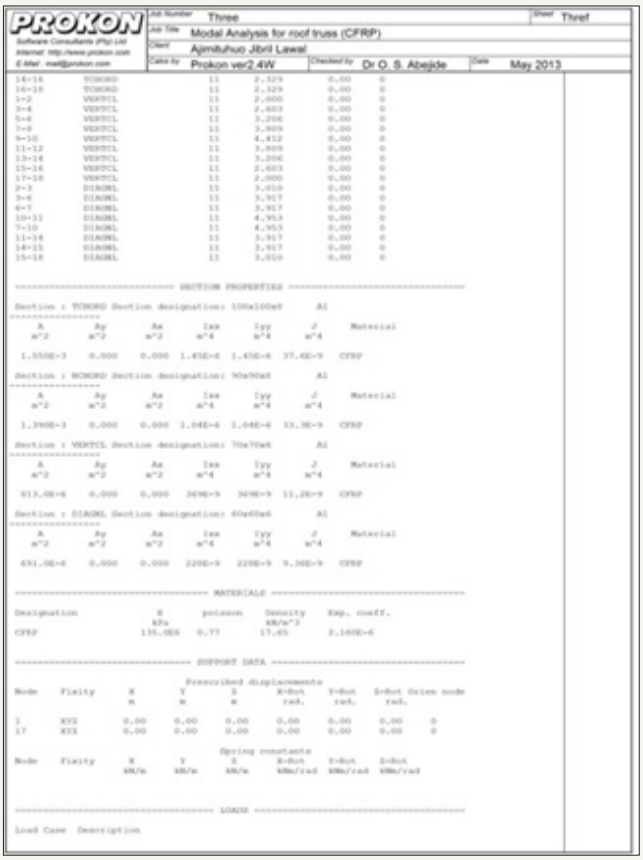
---------- NODAL POINT COORDINATES ----------

Node No	X-coord m	Y-coord m	Z-coord m	Node No	X-coord m	Y-coord m	Z-coord m
1	0.000	0.000	0.000	2	0.000	2.000	0.000
3	2.250	0.000	0.000	4	2.250	2.603	0.000
5	4.500	0.000	0.000	6	4.500	3.206	0.000
7	6.750	0.000	0.000	8	6.750	3.809	0.000
9	9.000	0.000	0.000	10	9.000	4.412	0.000
11	11.250	0.000	0.000	12	11.250	3.809	0.000
13	13.500	0.000	0.000	14	13.500	3.206	0.000
15	15.750	0.000	0.000	16	15.750	2.603	0.000
17	18.000	0.000	0.000	18	18.000	2.000	0.000

---------- ELEMENT DATA ----------

Beam	Secn. type	Fixity	Length m	β (°)	Group no.
1-3	BCHORD	11	2.250	0.00	0
3-5	BCHORD	11	2.250	0.00	0
5-7	BCHORD	11	2.250	0.00	0
7-9	BCHORD	11	2.250	0.00	0
9-11	BCHORD	11	2.250	0.00	0
11-13	BCHORD	11	2.250	0.00	0
13-15	BCHORD	11	2.250	0.00	0
15-17	BCHORD	11	2.250	0.00	0
2-4	TCHORD	11	2.329	0.00	0
4-6	TCHORD	11	2.329	0.00	0
6-8	TCHORD	11	2.329	0.00	0
8-10	TCHORD	11	2.329	0.00	0
10-12	TCHORD	11	2.329	0.00	0
12-14	TCHORD	11	2.329	0.00	0

Figure 21:



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E-Mail: mail@prokon.com

Job Number	Three	Sheet	Three
Job Title	Modal Analysis for roof truss (CFRP)		
Client	Ajimituhuo Jibril Lawal		
Calcs by	Prokon ver2.4W	Checked by: Dr O. S. Abejide	Date: May 2013

14-16	TCHORD	11	2.329	0.00	0
16-18	TCHORD	11	2.329	0.00	0
1-2	VERTCL	11	2.000	0.00	0
3-4	VERTCL	11	2.603	0.00	0
5-6	VERTCL	11	3.206	0.00	0
7-8	VERTCL	11	3.809	0.00	0
9-10	VERTCL	11	4.412	0.00	0
11-12	VERTCL	11	3.809	0.00	0
13-14	VERTCL	11	3.206	0.00	0
15-16	VERTCL	11	2.603	0.00	0
17-18	VERTCL	11	2.000	0.00	0
2-3	DIAGNL	11	3.010	0.00	0
3-4	DIAGNL	11	3.917	0.00	0
4-7	DIAGNL	11	3.917	0.00	0
10-11	DIAGNL	11	4.953	0.00	0
9-10	DIAGNL	11	4.953	0.00	0
11-14	DIAGNL	11	3.917	0.00	0
14-15	DIAGNL	11	3.917	0.00	0
15-18	DIAGNL	11	3.010	0.00	0

---------- SECTION PROPERTIES ----------

Section : TCHORD Section designation: 100x100x8 A1

A m^2	Ay m^2	Az m^2	Ixx m^4	Iyy m^4	J m^4	Material
1.550E-3	0.000	0.000	1.45E-6	1.45E-6	37.4E-9	CFRP

Section : BCHORD Section designation: 90x90x8 A1

A m^2	Ay m^2	Az m^2	Ixx m^4	Iyy m^4	J m^4	Material
1.390E-3	0.000	0.000	1.04E-6	1.04E-6	33.3E-9	CFRP

Section : VERTCL Section designation: 70x70x6 A1

A m^2	Ay m^2	Az m^2	Ixx m^4	Iyy m^4	J m^4	Material
613.0E-6	0.000	0.000	369E-9	369E-9	11.2E-9	CFRP

Section : DIAGNL Section designation: 60x60x6 A1

A m^2	Ay m^2	Az m^2	Ixx m^4	Iyy m^4	J m^4	Material
691.0E-6	0.000	0.000	220E-9	220E-9	9.36E-9	CFRP

---------- MATERIALS ----------

Designation	E kPa	poisson	Density kN/m^3	Exp. coeff.
CFRP	135.0E6	0.77	17.65	2.160E-6

---------- SUPPORT DATA ----------

Prescribed displacements

Node	Fixity	X m	Y m	Z m	X-Rot rad.	Y-Rot rad.	Z-Rot rad.	Orien node
1	XYZ	0.00	0.00	0.00	0.00	0.00	0.00	0
17	XYZ	0.00	0.00	0.00	0.00	0.00	0.00	0

Spring constants

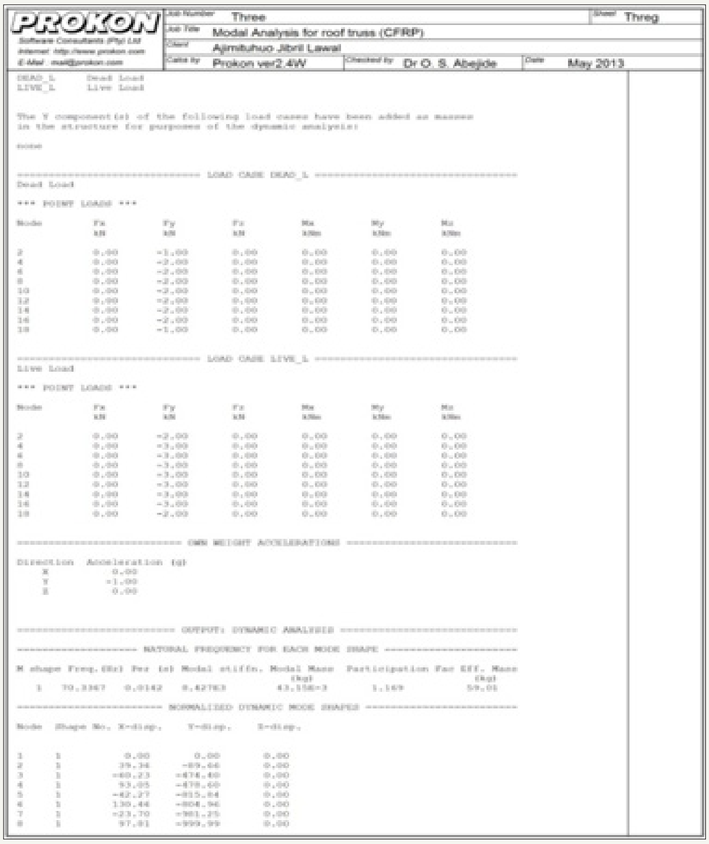
Node	Fixity	X kN/m	Y kN/m	Z kN/m	X-Rot kNm/rad	Y-Rot kNm/rad	Z-Rot kNm/rad

---------- LOADS ----------

Load Case Description

Figure 22:

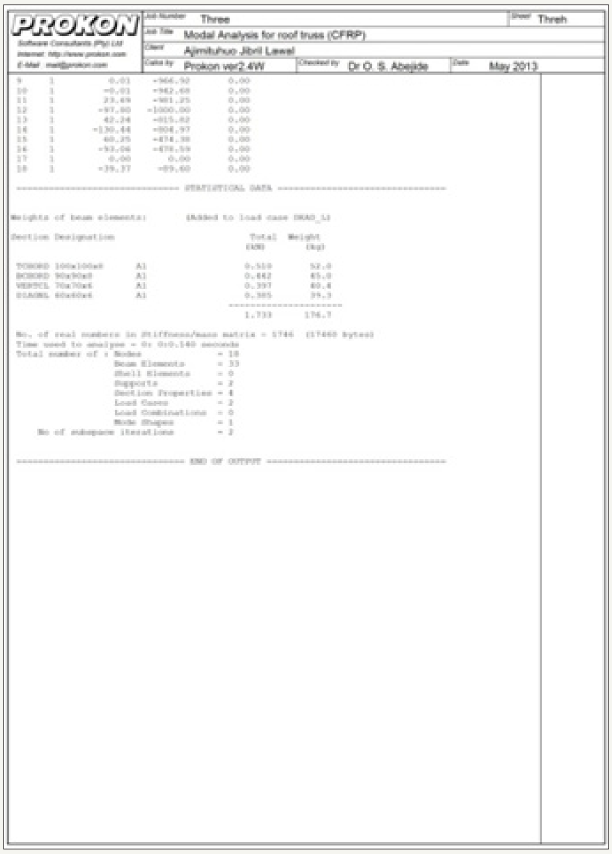
How to cite this article: Ajimituhuo J, Abejide O. Effectiveness and Shape Design of CFRP Structural Sections in Roof Trusses . 5(5). RDMS.000624.2018.
DOI: 10.31031/RDMS.2018.05.000624



PROKON Software Consultants (Pty) Ltd Internet: http://www.prokon.com E-Mail : mail@prokon.com	Job Number: Three	Sheet: Threg
	Job Title: Modal Analysis for roof truss (CFRP)	
	Client: Ajimituhuo Jibril Lawal	
	Calcs by: Prokon ver2.4W	Checked by: Dr O. S. Abejide — Date: May 2013

```
DEAD_L      Dead Load
LIVE_L      Live Load

The Y component(s) of the following load cases have been added as masses
in the structure for purposes of the dynamic analysis:

none

=============================== LOAD CASE DEAD_L ===================================
Dead Load

*** POINT LOADS ***

Node         Fx        Fy        Fz        Mx        My        Mz
             kN        kN        kN        kNm       kNm       kNm

2            0.00     -1.00      0.00      0.00      0.00      0.00
4            0.00     -2.00      0.00      0.00      0.00      0.00
6            0.00     -2.00      0.00      0.00      0.00      0.00
8            0.00     -2.00      0.00      0.00      0.00      0.00
10           0.00     -2.00      0.00      0.00      0.00      0.00
12           0.00     -2.00      0.00      0.00      0.00      0.00
14           0.00     -2.00      0.00      0.00      0.00      0.00
16           0.00     -2.00      0.00      0.00      0.00      0.00
18           0.00     -1.00      0.00      0.00      0.00      0.00

=============================== LOAD CASE LIVE_L ===================================
Live Load

*** POINT LOADS ***

Node         Fx        Fy        Fz        Mx        My        Mz
             kN        kN        kN        kNm       kNm       kNm

2            0.00     -2.00      0.00      0.00      0.00      0.00
4            0.00     -3.00      0.00      0.00      0.00      0.00
6            0.00     -3.00      0.00      0.00      0.00      0.00
8            0.00     -3.00      0.00      0.00      0.00      0.00
10           0.00     -3.00      0.00      0.00      0.00      0.00
12           0.00     -3.00      0.00      0.00      0.00      0.00
14           0.00     -3.00      0.00      0.00      0.00      0.00
16           0.00     -3.00      0.00      0.00      0.00      0.00
18           0.00     -2.00      0.00      0.00      0.00      0.00

============================ OWN WEIGHT ACCELERATIONS ==============================

Direction  Acceleration (g)
    X           0.00
    Y          -1.00
    Z           0.00


=========================== OUTPUT: DYNAMIC ANALYSIS ===============================

---------------------- NATURAL FREQUENCY FOR EACH MODE SHAPE -----------------------

M shape Freq.(Hz) Per (s) Modal stiffn. Modal Mass  Participation Fac Eff. Mass
                                          (kg)                          (kg)
   1   70.3367   0.0142   8.42783       43.15E-3         1.169            59.01

========================= NORMALIZED DYNAMIC MODE SHAPES ===========================

Node  Shape No. X-disp.     Y-disp.     Z-disp.


1      1          0.00        0.00       0.00
2      1         39.34      -89.66       0.00
3      1        -60.23     -474.40       0.00
4      1         93.05     -479.60       0.00
5      1        -42.27     -815.84       0.00
6      1        130.44     -804.96       0.00
7      1        -23.70     -981.25       0.00
8      1         97.81     -999.99       0.00
```

Figure 23:



PROKON Software Consultants (Pty) Ltd Internet: http://www.prokon.com E-Mail : mail@prokon.com	Job Number: Three	Sheet: Threh
	Job Title: Modal Analysis for roof truss (CFRP)	
	Client: Ajimituhuo Jibril Lawal	
	Calcs by: Prokon ver2.4W	Checked by: Dr O. S. Abejide — Date: May 2013

```
9      1         -0.01     -966.92       0.00
10     1         -0.01     -942.68       0.00
11     1         23.69     -981.25       0.00
12     1        -97.80    -1000.00       0.00
13     1         42.24     -815.82       0.00
14     1       -130.44     -804.97       0.00
15     1         60.25     -474.38       0.00
16     1        -93.06     -478.59       0.00
17     1         -0.00        0.00       0.00
18     1        -39.37      -89.60       0.00

================================ STATISTICAL DATA =================================


Weights of beam elements:       (Added to load case DEAD_L)

Section Designation                         Total   Weight
                                            (kN)      (kg)

 TCHORD 100x100x8       A1                  0.510      52.0
 BCHORD 90x90x8         A1                  0.442      45.0
 VERTCL 70x70x6         A1                  0.397      40.4
 DIAGNL 60x40x6         A1                  0.385      39.3
                                         ========================
                                            1.733     176.7

 No. of real numbers in Stiffness/mass matrix = 1746  (17460 bytes)
 Time used to analyse = 0: 0:0.140 seconds
 Total number of : Nodes                 = 18
                   Beam Elements         = 33
                   Shell Elements        = 0
                   Supports              = 2
                   Section Properties    = 4
                   Load Cases            = 2
                   Load Combinations     = 0
                   Mode Shapes           = 1
     No of subspace iterations           = 2


================================= END OF OUTPUT ==================================
```

Figure 24:

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Table 3: Properties of steel and CFRP.

Designation	E(kPa)	Poisson	Density kN/m³	Exp. Coeff
STEEL 350W	$200.0E^{6}$	0.3	77.00	$11.70E^{-6}$
CFRP	$135.0E^{6}$	0.77	17.65	$2.160E^{-6}$

Discussion of Result

From the results obtained from Finite Element Analysis using PROKON software, there are several differences but the pronounced difference is obtained from the section weights outlined below (Table 4).

Table 4: This gives 77% weight saving for steel when CFRP is used. This shows that the steel truss is about five times heavier than the CFRP truss.

Section Designation	WT (Steel)	WT(CFRP)
T chord 100×100×8 A1	226.7kg	52.0kg
B chord 90×90×8 A1	196.4kg	45.0kg
Vertical 70×70×6 A1	176.4kg	40.4kg
Diagonal 60×60×6 A1	171.4kg	39.3kg
	770.9kg	176.7kg

For Linear Analysis

In the FEM analysis using PROKON software, the steel truss was found to withstand deflection more than the CFRP. In modal analysis, it was obtained that the steel trussvibrate more than the CFRP truss with an average of 0.0244/s and 0.0142/s respectively. This gives an average of 41.8% of vibration saved when CFRP is used instead of steel (Table 5).

Table 5:

Steel	CFRP
· Max Deflection for DEAD LOAD case X= -0.18mm at node 14 Y= -1.34mm at node 8	· Max Deflection for DEAD LOAD case X= -0.20mm at node 14 Y= -1.5mm at node 12
· Max Deflection for LIVE LOAD case X= -0.19mm at node 14 Y= -1.37mm at node 12	· Max Deflection for LIVE LOAD case X= -0.28mm at node 14 Y= -2.04mm at node 8

Conclusion and Recommendations

The aim of this study is to show the effectiveness of CFRP as a material for the structural sections of a roof truss is achieved as the results obtained from the Finite Element Analysis using PROKON reveals its effectiveness and deficiency as well; depending on the aim and focus of the design. For instance, where the weight of the structure is the subject of consideration in the design, CFRP proves to be more economical by a large percentage from this study. Also, we can deduce that even where strength of the structure is of essence, CFRP can still be considered over steel because the steel truss withstood deflections more than CFRP only with a small difference.

References

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