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Comparative Design of Some Nigerian Timber Roof Trusses Using BS5268.

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ABSTRACT: This work was done to determine and compare the performance of ten different roof trusses. The truss design was done in accordance with BS5268 part 3 (1998). The design load was resolved to act on the joints of the trusses. The trusses were then analysed using method of joints, to determine the compressive and tensile axial forces acting on the truss members.
The truss members wereanalysed as simply supported beams. Clapyron's theorem of three moment was used to determine the support moments, while the span moments and shear forces on the members were determined using method of section.
The values of applied and permissible stresses of the trusses members are compared between the trusses. The ratio of the values of the applied to permissible stresses are determined for each truss, and compared against values of from other trusses. It was found that the lower the ratio value, the higher the adequacy of the truss member against the stresses. The average stress ratio for the different trusses were also calculated. The ratio of the applied to permissible stresses were used to evaluate the performances of the various trusses in different conditions. The comparisons were done with respect to the values of applied to permissible stress ratios.
From the results obtained, the flat truss had a better performance against the others on a general basis, but this type of truss usually has drainage problems. The attic truss performed better against bending and shear stress. The mono pitch roof truss performed better against tensile stress, while the gambrel truss performed better against compressive stress.

Keywords; *Design, Forces, Roof, Timber, and Truss*

I. INTRODUCTION

A roof is a very important part of a building without which a building is not complete, this makes it a very important structure in civil engineering whose structural adequacy needs to be addressed to avoid failure which can pose great peril and inconveniences to lives and properties. A structure is an assemblage of components which are connected in such a way thatthe structure can withstand the action of loads that are applied to it. These loads may be due to gravity, wind, ground shaking, impact, temperature, or other environmental sources (Connor and Faraji, 2012). Important examples related to civil engineering include buildings, bridges, and towers; and in other branches of engineering, ship and aircraft frames, tanks, pressure vessels, mechanical systems, and electrical supporting structures are important. When designing a structure to serve a specified function for public use, the engineer must account for its safety, esthetics, and serviceability, while taking into consideration economic and environmental constraints (Hibbeler, 2012).In recent years, researchers around the world seek to develop new and innovative structural forms that can perform better and cheaper than the existing one. As time continues to fly, more valuable forms would also be discovered to replace the ones which would be discovered in the nearest future. Therefore, it is the task of structural engineers of this century to research and produce structural forms which supersedes the ones created by the engineers of the preceding century, this makes it a dynamic system.

II. STATEMENT OF PROBLEM

Roofs are usually designed with major consideration of their aesthetic requirements and with little consideration of their structural requirements.People often pay more attention to the aesthetic value of the roof a lot more than its stability which results in structural failure of the roof. The failure of roofs is largely due to inadequate design of the support structure, which in turn is due to negligence, ignorance and lack of awareness of the importance of the structural value of the roof which is an integral part of a building.

III. AIM AND OBJECTIVES OF RESEARCH

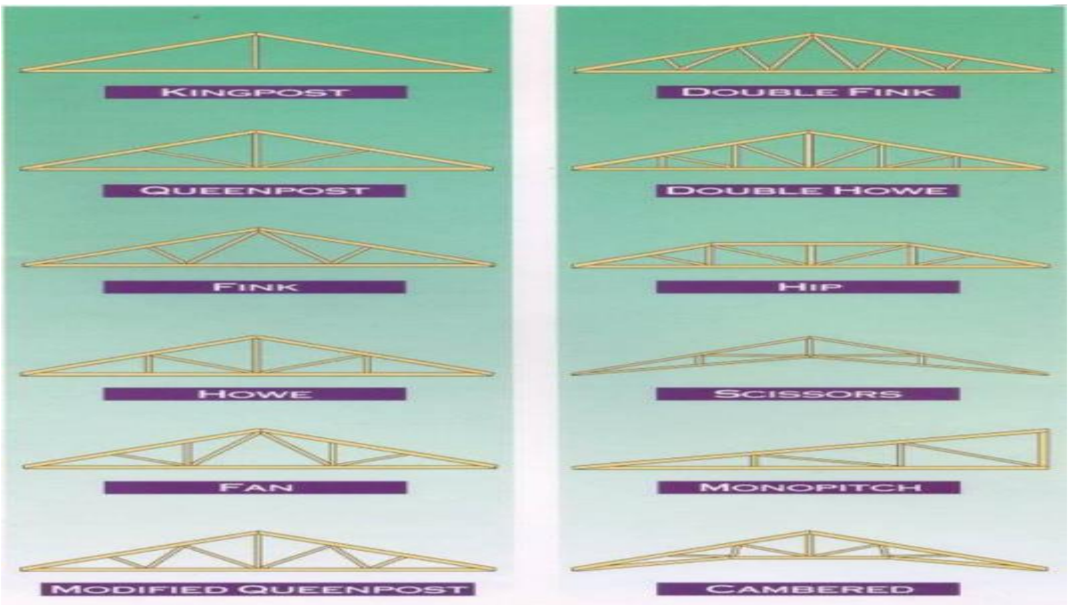
With the problem stated in the previous section, the aim of this research work is to determine and compare the structural adequacies of various roof truss configurations in various conditions. This is accompanied by objectives stated below.

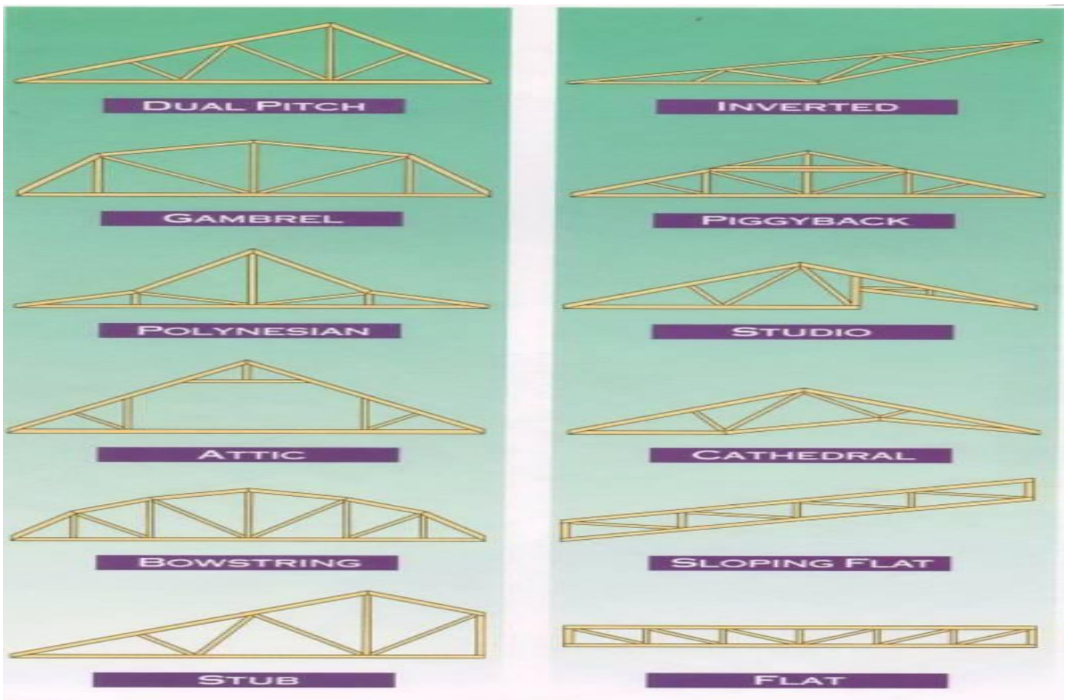
- To determine the roof truss type based on configuration that is more adequate for resisting tensile stress.

- To determine the roof truss type that is more adequate for resisting compressive stress.
- To determine the roof truss type that is more adequate in resisting shear stress
- To determine the roof truss type that is more adequate for resisting bending stress.
- To determine the roof truss type that is generally more adequate in resisting the pressure imposed on it.
- To enlighten readers on the importance of the proper designing of the roof as a structural element.

IV. LITERATURE REVIEW

Throughout the history, mankind's need for shelter was second only to the need for food. Prehistoric man took shelter under a roof of stone, arguably the best protection from the elements. It is a popular adage that people usually say "I want to put a roof over my head" However; this popular statement involves a lot. To a structural engineer, the statement means to analyze, design and construct with aesthetic, economy and safety a roof system. To talk about aesthetic is to talk about shape and configuration, to talk about economy is to talk about the cost of the roof and to talk of safety brings us to deflection as one of the serviceability requirements (Ezeagu *et al*., 2012). Imagine for a moment that you aren't inside. You don't have a roof over your head or walls about you. The burning sun beats down upon your head, the wind whips your papers around. Dust swirls around as you try to read this. You can't concentrate, it's too hot or too cold. Insects bother you, raindrops soak your paper and your computer (Roy and Roger, 2000).The primary function of a roof is to protect the building below from the weather. In order to satisfactorily perform this function over a period of years, it must be strong, stable and durable. In addition, roofs must provide good thermal insulation and prevent the spread of fire from adjacent or adjoining properties (Duncan and Derek, 2000).A truss is an assemblage of long, slender structural elements that are connected at their ends. . The role of trusses in engineering Structures should not be underrated, as they form a significant component in various engineering structures (Ezeagu and Offor, 2011). Trusses and substantial use in modern construction, for instance as towers, bridges, scaffolding, etc.Palladio was reportedly the first to build a timber truss bridge of significant span 33m between trent and Bassano (Timoshenkon, 1953). The most important property of any structure, truss or not, is that it be stable; i.e. not fall down. For a truss structure to be considered stable, none of the joints can be out of force balance. Trussed roof assembly design methodology has changed little over the past 30 years. Each truss is designed to carry full tributary area load (Ronald and Timothy, 1991).Trusses consist of slender elements, usually arranged in triangular fashion. Planar trusses are composed of members that lie in the same plane and are frequently used for bridge and roof support, whereas space trusses have members extending in three dimensions and are suitable for derricks and towers (Hibbeler, 2012).The engineer is usually influenced by the architecture's considerations, the type and length of material, support conditions, span and economy, and probably chooses from three basic truss types: pitched (minor-or due pitch), parallel chord or bowstring trusses (Ezeagu and Nwokoye, 2009). There are examples of trusses all around us, many are hidden from sight underneath cladding or bricking but there are also many good examples of truss structures left exposed. The range of trusses in use today is quite diverse, they vary enormously in shape and size. The diagrams below shows a range of different type of truss, notice the variety of shapes and the contrasting amounts of complexity (Ezeagu and Nwokoye, 2009).





V. MATERIALS AND METHOD

Materials:

Ten roof trusses of different types (based on configuration) of roof trusses were designed with timber species- Ekimi of assumed density 1136Kg/m^3, For a fair and easy comparison, they were all designed using timber grade strength Sc5 with properties;

- Bending parallel to grain ($\ddot{O}_{m,//,g}$) = 10N/mm^2
- Compression parallel to grain ($\ddot{O}_{c,//,g}$) = 8.7N/mm^2
- Tension parallel to grains ($\ddot{O}_{t,//,g}$) = 6.8N/mm^2
- Shear parallel to grain ($\delta_{//g}$) = 1N/mm^2
- E_{mean} = 10700N/mm^2
- E_{min}=7100N/m^2

The ten trusses resist load applied to them in different ways due to the different configurations of their members. The names of the trusses are given below;

1. Double howe. 2.Mono pitch. 3. Stub. 4. Cathedral. 5. Sloping flat. 6.Polynesian.7.Hip. 8. Gambrel. 9. Attic. 10. Flat

They were designed with equal length of 12m and a rise of 2m, except for the flat truss which has zero slope.
The rafters of all the trusses has a cross section of 150mm x 150mm, with geometrical properties;

- Area = 22.5*10^{3}mm^2
- I_{z-z} = 42.2 *10^{6}mm^4
- Z_{x-x} = 563 * 10^{6}mm^4
- r_{x-x} = 43.3mm
- r_{z-z} = 43.3mm

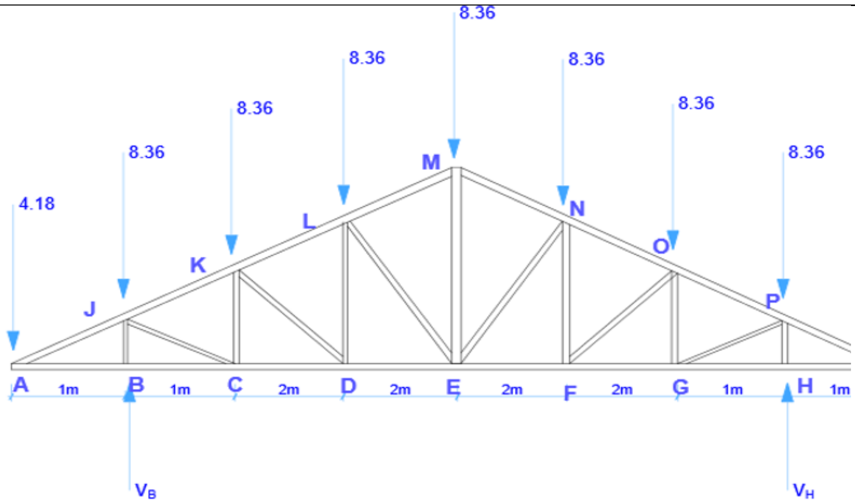
The strength class properties, together with the geometrical properties and modification factors determine the permissible stresses of the truss members. While the method of load application and the configuration of members determine the applied stresses. For satisfactory design of an element at ultimate limit states, the design resistance or capacity of the element or section must be greater than or equal to the ultimate design load effects.

Methodology

This section provides a brief introduction to the techniques used for truss design in this research work. The design of the truss members began with load analysis on the rafters and purlins. The load analysis of the rafters were done according to BS 5268 part 3, while that of the purlins according to BS 5268 part 7. This research work considers only live load and dead load, excluding wind load. The loads are applied to the joints and the trusses are analysed using the method of joint. This gives the tensile and compressive axial forces acting on the members. The members are assumed to be simply supported, and are analysed using clapyron's theorem of three moments to determine the support moments, and method of section to determine the span moments and shear forces. Designs are usually done in ultimate limit states, so the maximum of the axial (compressive and tensile), shear and bending stresses were checked against the permissible values of the section and grade of the timber adopted. The applied, permissible and ratio of applied to permissible of the stresses are determined for the various truss configurations. These values are plotted in charts which are used in the analysis and comparison of the performances of the trusses in different conditions.

Truss Design.

Reference	Calculations	Output
	Load Analysis	
	• Dead load on rafter	
	Weight of roof tiles = $0.575KN/m^2$	
	Weight of battens and rafters = $0.11KN/m^2$	
	Total dead load = 0.575 + 0.11 = $0.685KN/m^2$	
	• Ceiling load = $0.25KN/m^2$	
	• Imposed load on rafter = $0.75KN/m^2$ (ignoring wind load)	
	Actual Design Load of Rafter is given by	
	• Ceiling load = $0.25KN/m^2$	
	• Assumed weight = $0.11KN/m^2$	
	• Dead load = $0.685KN/m^2$	
	Total = $1.045KN/m^2$	
	Total design load of rafter = design load * bay spacing	
	= 1.045 * 4.0 = $4.18KN/m^2$	
	Timber strength class Sc5	
	Bending parallel to grain ($Ö_{m,//,g}$) = $10N/mm^2$	
	Compression parallel to grain ($Ö_{c,//,g}$) = $8.7N/mm^2$	
	Tension parallel to grains ($Ö_{t,//,g}$) = $6.8N/mm^2$	
	Shear parallel to grain ($\delta_{//,g}$) = $1N/mm^2$	
	$E_{mean} = 10700N/mm^2$	
	$E_{min}=7100N/m^2$	
	Geometrical Properties	
	Adopt a trial section of 150 x 150mm	
	Area = $22.5*10^3mm^2$	
	$I_{z-z} = 42.2 *10^6mm^4$	
	$Z_{x-x} = 563 * 10^6mm^4$	
	$r_{x-x} = 43.3mm$	
	$_{z-z} = 43.3mm$	
	Effective length of member = 0.85L	
	Modification Factors	
	Moisture modification factor, K_{12} =1.0	
	Load duration factor, k_3 = 1.0	
	Load sharing factor, k_8 = 1.1	
	Depth factor, $k_7 = [^{0.11}$	
	Width factor, $k_{14} = [^{0.11}$	
	Compression member factor = k_1	
	Truss 0ne (Double Howe)	
	Fig6: Double howe truss.	



Calculations

Tensile stress

Permissible tensile stress, $Ö_{t,adm} = k_2.k_3.k_{14}.Ö_{t,//,g}$

$= 1.0 * 1.0 * 1.079 * 6.8 = 7.347N/mm^2$

Applied tensile stress, $Ö_{t,a}$ = = = $3.52N/mm^2$

Bending stress

Permissible bending stress $Ö_{m,adm} = k_2.k_3.k_7.k_8.Ö_{m,//,g}$

$= 1.0 * 1.0 * 1.079 * 1.1 * 10 = 11.869N/mm$

Applied bending stress, $Ö_{m,a}$ = = = $3.694N/mm^2$

Compressive stress

Permissible compressive stress, $Ö_{c,adm} = k_2.k_3.k_7.k_8.k_{12}.\ Ö_{c,//,g}$

$= 1.0 * 1.0 * 1.079 * 1.1 * 0.792 * 8.7 = 8.178N/mm^2$

Applied compressive stress, $Ö_{c,a}$= = = $2.939N/mm^2$

Shearstress

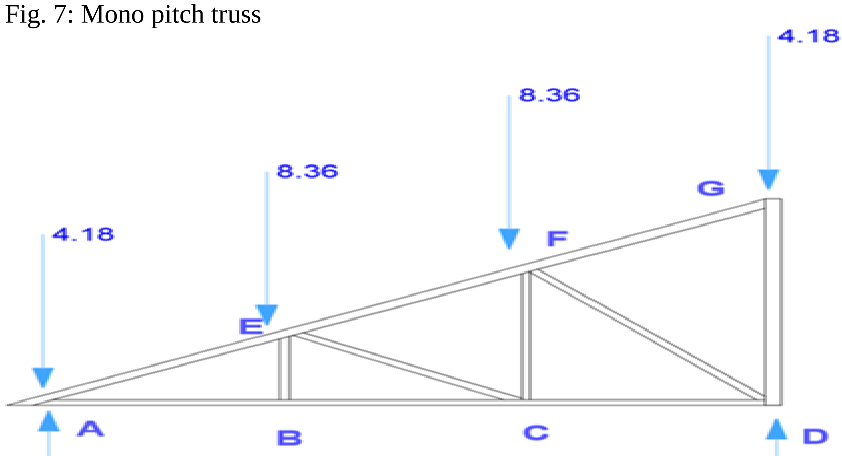
Permissible shear stress, $\tau_{adm} = k_2.k_3.k_8.\delta_g$

$= 1.0 * 1.0 * 1.1 * 1.0 = 1.1N/mm^2$

Applied shear stress, τ_a= = = $0.359N/mm^2$

Truss 2 (Monopitch)

Fig. 7: Mono pitch truss



Tensile stress

Permissible tensile stress, $Ö_{t,adm} = k_2.k_3.k_{14}.Ö_{t,//,g}$

$= 1.0 * 1.0 * 1.079 * 6.8 = 7.337KN/m^2$

Applied tensile stress, $Ö_{t,a}$ = = =$1.131N/mm^2$

Bendingstress

Permissible bending stress $Ö_{m,adm} = k_2.k_3.k_7.k_8.Ö_{m,//,g}$

$= 1.0 * 1.0 * 1.079 * 1.1 * 10 = 11.869N/mm^2$

Applied bending stress, $Ö_{m,a}$ = = = $12.202N/mm^2$

Compressive stress

Permissible compressive stress, $Ö_{c,adm} = k_2.k_3.k_7.k_8.k_{12}.Ö_{c,//,g}$

$= 1.0 * 1.0 * 1.079 * 1.1 * 0.542 * 8.7 = 5.597 N/mm^2$

Applied compressive stress, $Ö_{c,a} = \ = \ = 1.129 N/mm^2$

Shearstress

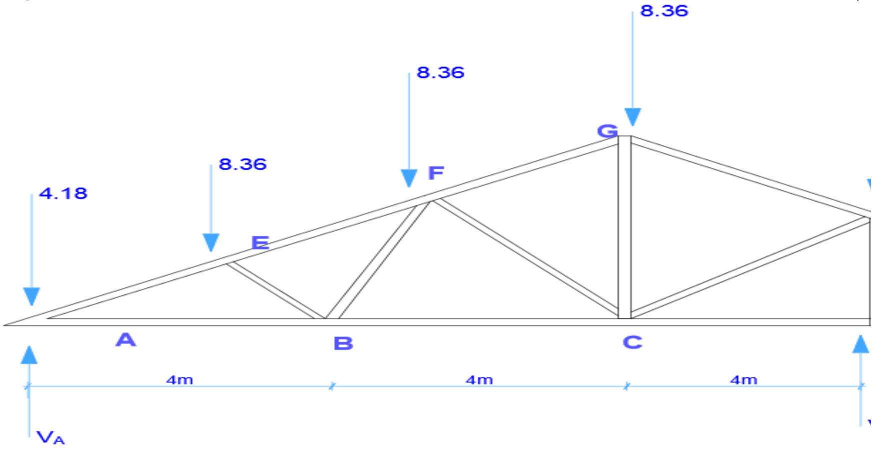
Permissible shear stress, $ʈ_{adm} = k_2.k_3.k_8.δ_g$

$= 1.0 * 1.0 * 1.1 * 1.0 = 1.1 N/mm^2$

Applied shear stress, $ʈ_a = \ = \ = 0.452 N/mm^2$

Truss 3 (Stub)

Fig. 8: Stub truss



Calculations

Tensile stress

Permissible tensile stress, $Ö_{t,adm} = k_2.k_3.k_{14}.Ö_{t,//,g}$

$= 1.0 * 1.0 * 1.079 * 6.8 = 7.337 N/mm^2$

Applied tensile stress, $Ö_{t,a} = \ = \ = 2.297 N/mm^2$

Bending stress

Permissible bending stress $Ö_{m,adm} = k_2.k_3.k_7.k_8.Ö_{m,//,g}$

$= 1.0 * 1.0 * 1.079 * 1.1 * 10 = 11.869 N/mm^2$

Applied bending stress, $Ö_{m,a} = \ = \ = 11.22 N/mm^2$

Compressive stress

Permissible compressive stress, $Ö_{c,adm} = k_2.k_3.k_7.k_8.k_{12}.Ö_{c,//,g}$

$= 1.0 * 1.0 * 1.079 * 1.1 * 0.552 * 8.7 = 5.70 N/mm^2$

Applied compressive stress, $Ö_{c,a} = \ = \ = 3.084 N/mm^2$

Bending stress

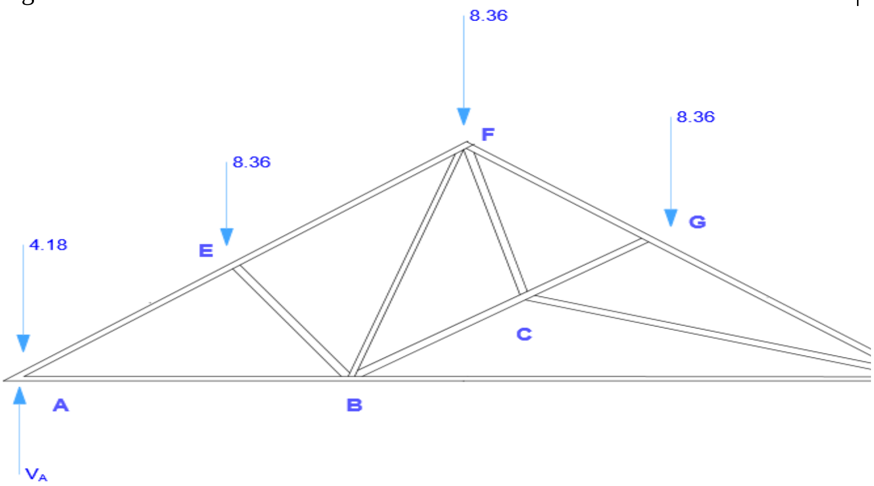
Permissible shear stress, $ʈ_{adm} = k_2.k_3.k_8.δ_g$

$= 1.0 * 1.0 * 1.1 * 1.0 = 1.1 N/mm^2$

Applied shear stress, $ʈ_a = \ = \ = 0.443 N/mm^2$

Truss 4 (Cathedral)

Fig. 9: Cathedral truss



Calculations

Tensile stress

Permissible tensile stress, $Ö_{t,adm} = k_2.k_3.k_{14}.Ö_{t,//,g}$

$= 1.0 * 1.0 * 1.079 * 6.8 = 7.67KN/m^2$

Applied tensile stress, $Ö_{t,a}$ = = = $2.272N/mm^2$

Bending stress

Permissible bending stress $Ö_{m,adm} = k_2.k_3.k_7.k_8.Ö_{m,//,g}$

$= 1.0 * 1.0 * 1.079 * 1.1 * 10 = 11.87N/mm^2$

Applied bending stress, $Ö_{m,a}$ = = = $9.254N/mm^2$

Compressive stress

Permissible compressive stress, $Ö_{c,adm} = k_2.k_3.k_7.k_8.k_{12}.\ Ö_{c,//}$

$= 1.0 * 1.0 * 1.079 * 1.1 * 0.797 * 8.7 = 8.23N/mm^2$

Applied compressive stress, $Ö_{c,a}$= = = $3.88N/mm^2$

Shear stress

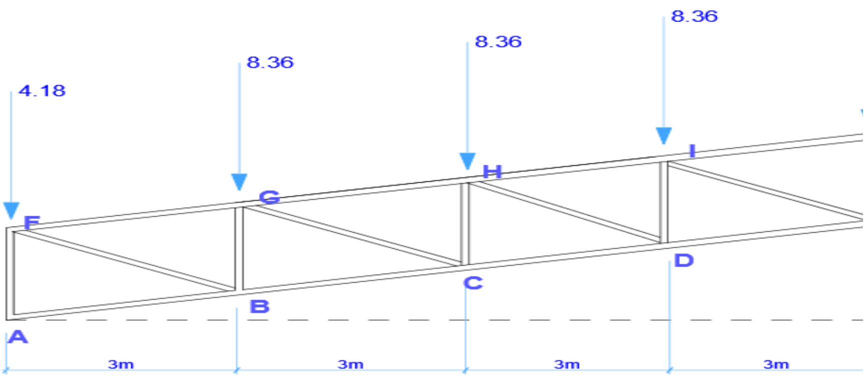
Permissible shear stress, $ʈ_{adm} = k_2.k_3.k_8.δ_g$

$= 1.0 * 1.0 * 1.1 * 1.0 = 1.1N/mm^2$

Applied shear stress, $ʈ_a$= = = $0.367N/mm^2$

Truss 5 (Sloping Flat)

Fig. 10: Sloping flat truss



Calculations

Tensile stress

Permissible tensile stress, $Ö_{t,adm} = k_2.k_3.k_{14}.Ö_{t,//,g}$

$= 1.0 * 1.0 * 1.079 * 6.8 = 7.334N/mm^2$

Applied tensile stress, $Ö_{t,a}$ = = = $4.089N/mm^2$

Bending stress

Permissible bending stress $Ö_{m,adm} = k_2.k_3.k_7.k_8.Ö_{m,//,g}$

$= 1.0 * 1.0 * 1.079 * 1.1 * 10 = 11.869N/mm^2$

Applied bending stress, $Ö_{m,a}$ = = = $8.064N/mm^2$

Compressive stress

Permissible compressive stress, $Ö_{c,adm} = k_2.k_3.k_7.k_8.k_{12}.\ Ö_{c,//,g}$

$= 1.0 * 1.0 * 1.079 * 1.1 * 0.667 * 8.7 = 6.887N/mm^2$

Applied compressive stress, $Ö_{c,a}$= = = $4.578N/mm^2$

Shear stress

Permissible shear stress, $ʈ_{adm} = k_2.k_3.k_8.δ_g$

$= 1.0 * 1.0 * 1.1 * 1.0 = 1.1N/mm^2$

Applied shear stress, $ʈ_a$= = = $0.343N/mm^2$

Truss 6 (Polynesian)

Fig. 11: Polynesian truss

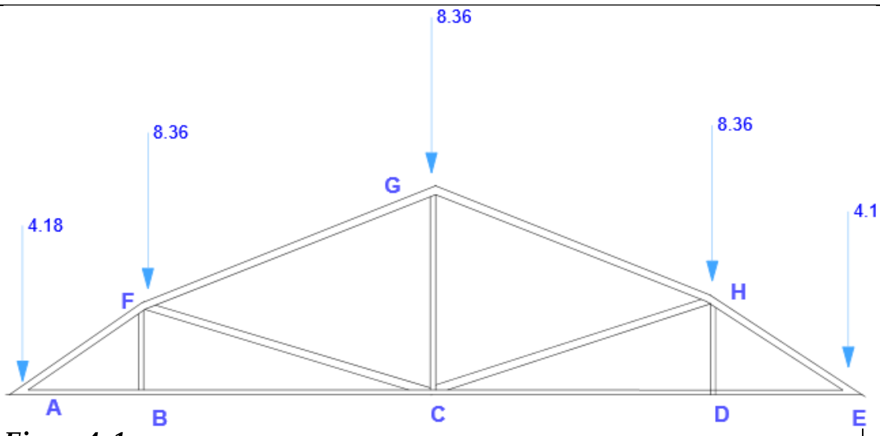


Figure 4. 1

Calculations

Tensile stress

Permissible tensile stress, Ö$_{t,adm}$ = $k_2.k_3.k_{14}$.Ö$_{t,//,g}$

= 1.0 * 1.0 * 1.079 * 6.8 = 7.337KN/m^2

Applied tensile stress, Ö$_{t,a}$ = = = 1.52N/mm^2

Bending stress

Permissible bending stress Ö$_{m,adm}$ = $k_2.k_3.k_7.k_8$.Ö$_{m,//,g}$

= 1.0 * 1.0 * 1.079 * 1.1 * 10 = 11.87N/mm^2

Applied bending stress, Ö$_{m,a}$ = = = 9.54N/mm^2

Compressive stress

Permissible compressive stress, Ö$_{c,adm}$ = $k_2.k_3.k_7.k_8.k_{12}$. Ö$_{c,//,g}$

= 1.0 * 1.0 * 1.079 * 1.1 * 0.370 * 8.7 = 3.473N/mm^2

Applied compressive stress, Ö$_{c,a}$= = = 1.324N/mm^2

Shear stress

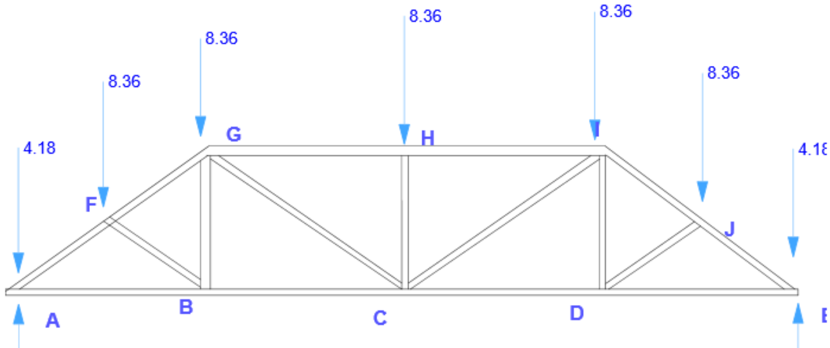
Permissible shear stress, ɽ$_{adm}$ = $k_2.k_3.k_8.\delta_g$

= 1.0 * 1.0 * 1.1 * 1.0 = 1.1N/mm^2

Applied shear stress, ɽ$_a$= = = 0.408N/mm^2

Truss 7 (Hip)

Fig. 12: Hip truss



Calculations

Tensile stress

Permissible tensile stress, Ö$_{t,adm}$ = $k_2.k_3.k_{14}$.Ö$_{t,//,g}$

= 1.0 * 1.0 * 1.079 * 6.8 = 7.337N/mm^2

Applied tensile stress, Ö$_{t,a}$ = = = 2.571N/mm^2

Bending stress

Permissible bending stress Ö$_{m,adm}$ = $k_2.k_3.k_7.k_8$.Ö$_{m,//,g}$

= 1.0 * 1.0 * 1.079 * 1.1 * 10 = 11.22N/mm^2

Applied bending stress, Ö$_{m,a}$ = = = 11.22N/mm^2

Compressive stress

Permissible compressive stress, Ö$_{c,adm}$ = $k_2.k_3.k_7.k_8.k_{12}$.Ö$_{c,//,g}$

= 1.0 * 1.0 * 1.079 * 1.1 * 0.344 * 8.7 = 3.552N/mm^2
Applied compressive stress, Ö$_{c,a}$= = = 1.775N/mm^2
Shear stress
Permissible shear stress, ʈ$_{adm}$ = $k_2.k_3.k_8.\delta_g$
= 1.0 * 1.0 * 1.1 * 1.0 = 1.1N/mm^2
Applied shear stress, ʈ$_a$= = = 0.659N/mm^2

Truss 8 (Gambrel)
Fig. 13: Gambrel truss

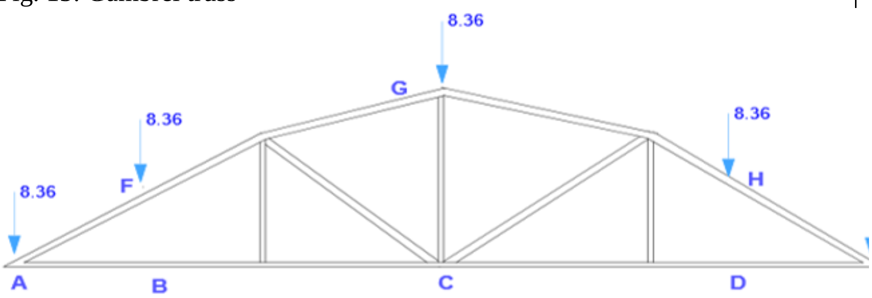
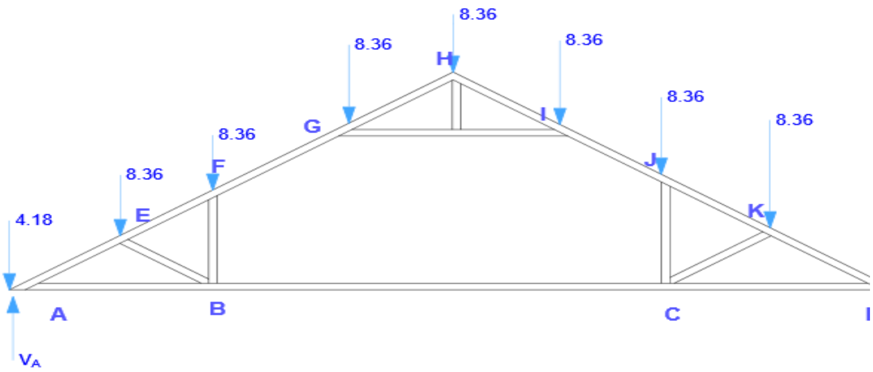


Figure 4. 2
Calculations
Tensile stress
Permissible tensile stress, Ö$_{t,adm}$ = $k_2.k_3.k_{14}$.Ö$_{t,//,g}$
= 1.0 * 1.0 * 1.079 * 6.8 = 7.337N/m^2
Applied tensile stress, Ö$_{t,a}$ = = = 1.246N/mm^2
Bending stress
Permissible bending stress Ö$_{m,adm}$ = $k_2.k_3.k_7.k_8$.Ö$_{m,//,g}$
= 1.0 * 1.0 * 1.079 * 1.1 * 10 = 11.869N/mm^2
Applied bending stress, Ö$_{m,a}$ = = = 9.55N/mm^2
Compressive stress
Permissible compressive stress, Ö$_{c,adm}$ = $k_2.k_3.k_7.k_8.k_{12}$.Ö$_{c,//,g}$
= 1.0 * 1.0 * 1.079 * 1.1 * 0.591 * 8.7 = 6.103N/mm^2
Applied compressive stress, Ö$_{c,a}$= = = 1.116N/mm^2
Shear stress
Permissible shear stress, ʈ$_{adm}$ = $k_2.k_3.k_8.\delta_g$
Applied shear stress, ʈ$_a$= = = 0.383N/mm^2

Truss 9 (Attic)
Fig. 14: Attic truss



Calculations

Tensile stress

Permissible tensile stress, $Ö_{t,adm} = k_2.k_3.k_{14}.Ö_{t,//,g}$

$= 1.0 * 1.0 * 1.079 * 6.8 = 7.337N/mm^2$

Applied tensile stress, $Ö_{t,a} = \; = \; = 4.113N/mm^2$

Bending stress

Permissible bending stress $Ö_{m,adm} = k_2.k_3.k_7.k_8.Ö_{m,//,g}$

$= 1.0 * 1.0 * 1.079 * 1.1 * 10 = 11.87N/mm^2$

Applied bending stress, $Ö_{m,a} = \; = \; = 1.989N/mm^2$

Compressive stress

Permissible compressive stress, $Ö_{c,adm} = k_2.k_3.k_7.k_8.k_{12}.\; Ö_{c,//,g}$

$= 1.0 * 1.0 * 1.079 * 1.1 * 0.851 * 8.7 = 8.787N/mm^2$

Applied compressive stress, $Ö_{c,a} = \; = \; = 4.114N/mm^2$

Shear stress

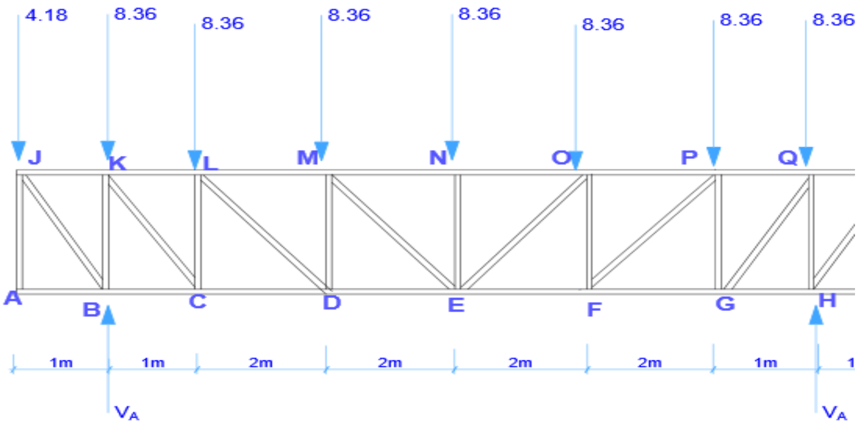
Permissible shear stress, $\tau_{adm} = k_2.k_3.k_8.\delta_g$

$= 1.0 * 1.0 * 1.1 * 1.0 = 1.1N/mm^2$

Applied shear stress, $\tau_a = \; = \; = 0.18N/mm^2$

Truss 10 (Flat)

Fig. 15: Flat truss



Calculations

Tensile stress

Permissible tensile stress, $Ö_{t,adm} = k_2.k_3.k_{14}.Ö_{t,//,g}$

$= 1.0 * 1.0 * 1.079 * 6.8 = 7.337N/m^2$

Applied tensile stress, $Ö_{t,a} = \; = \; = 1.984N/mm^2$

Bending stress

Permissible bending stress $Ö_{m,adm} = k_2.k_3.k_7.k_8.Ö_{m,//,g}$

$= 1.0 * 1.0 * 1.079 * 1.1 * 10 = 11.869N/mm^2$

Applied bending stress, $Ö_{m,a} = \; = \; = 3.393N/mm^2$

	Compressive stress **Permissible compressive stress,** $Ö_{c,adm} = k_2.k_3.k_7.k_8.k_{12}.Ö_{c,//,g}$ $= 1.0 * 1.0 * 1.079 * 1.1 * 0.797 * 8.7 = 8.230N/mm^2$ **Applied compressive stress,** $Ö_{c,a}= \; = \; = 1.775N/mm^2$ **Shear stress** **Permissible shear stress,** $\tau_{adm} = k_2.k_3.k_8.\delta_g$ $= 1.0 * 1.0 * 1.1 * 1.0 = 1.1N/mm^2$ **Applied shear stress,** $\tau_a= \; = \; = 0.659N/mm^2$	

VI. DISCUSSION

The results obtained from designs are plotted in charts. The charts plotted are with the values of the applied, permissible and ratio of the applied to permissible for the tensile, compressive, bending and shear stresses. These charts are used to compare and evaluate the adequacies of each truss in the respective areas. A fifth chart of the average ratios of each of the trusses is also plotted to compare the general performance of the various truss configurations. The charts are shown and discussed below.

Table 1: Tensile stress values

S/N	Truss type	Applied tensile stress (N/mm^2)	Permissible tensile stress (N/mm^2)	Ratio of applied to permissible tensile stress.
1	Double howe	2.439	7.337	0.332
2	Mono pitch	1.131	7.337	0.154
3	Stub	2.297	7.337	0.313
4	Cathedral	2.272	7.337	0.31
5	Sloping flat	4.089	7.337	0.557
6	Polynesian	1.526	7.337	0.207
7	Hip	2.571	7.337	0.35
8	Gambrel	1.264	7.337	0.172
9	Attic	4.113	7.337	0.561
10	Flat	1.984	7.337	0.27

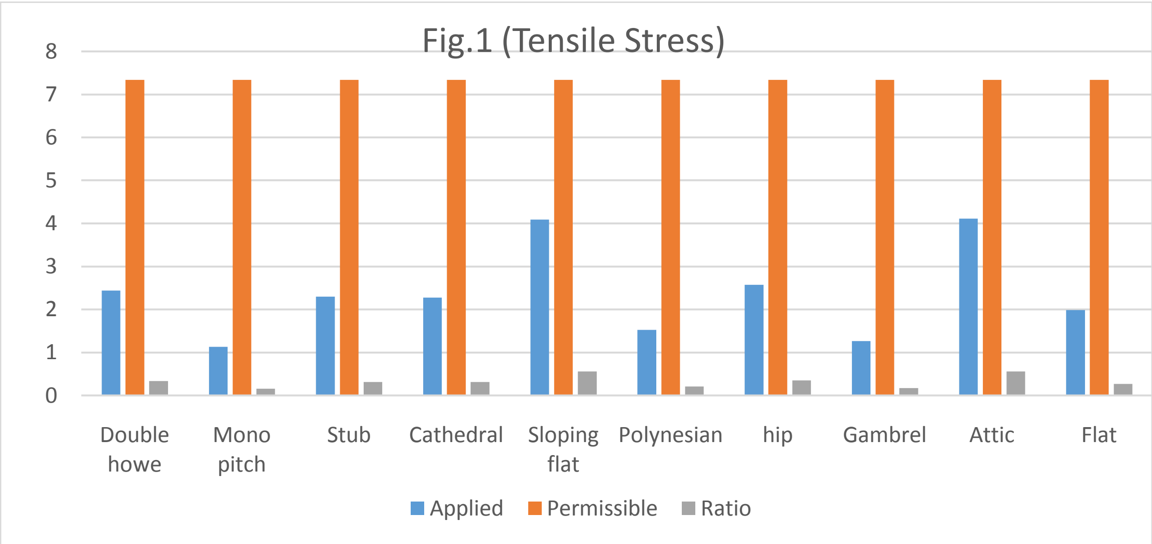


Table 2: Compressive stress values

S/N	Truss Type	Applied Compressive Stress (N/mm^2)	Permissible Compressive Stress (N/mm^2)	Ratio of Applied to Permissible Compressive Stress.
1	Double howe	2.939	8.178	0.359
2	Mono pitch	1.129	5.597	0.202
3	Stub	3.084	5.7	0.541
4	Cathedral	3.88	8.23	0.471
5	Sloping flat	4.578	6.887	0.665
6	Polynesian	1.324	3.473	0.381

7	Hip	1.775	3.552	0.5
8	Gambrel	1.116	6.103	0.183
9	Attic	4.114	8.787	0.468
10	Flat	2.2	8.23	0.267

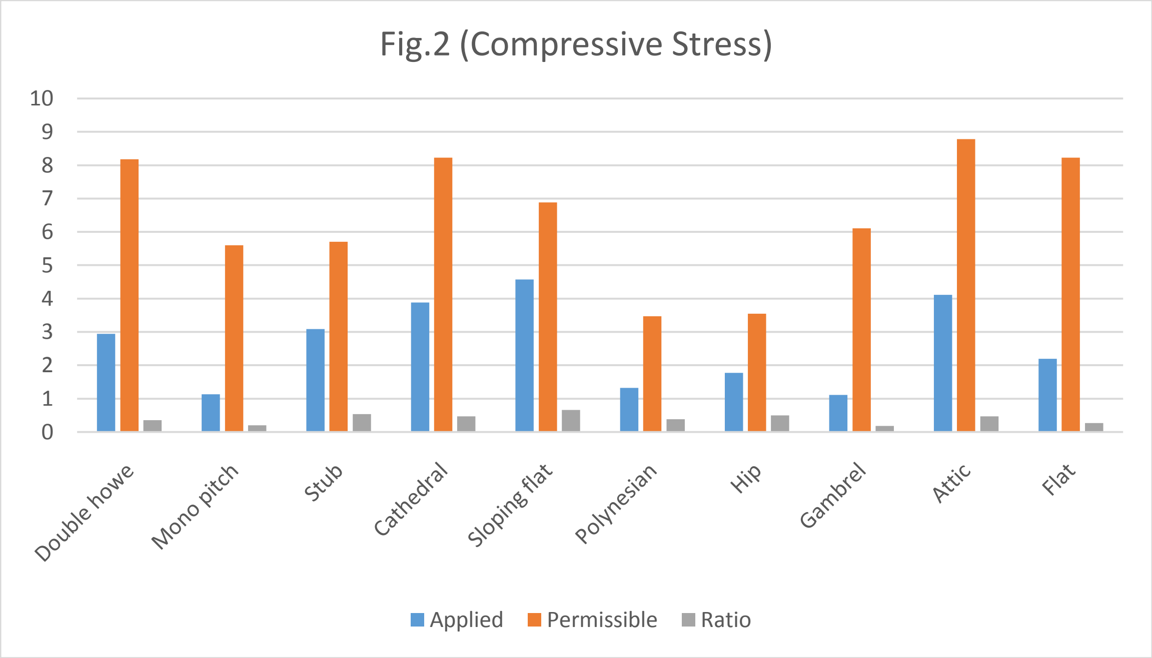


Table 3: Bending stress values

c	Truss Type	Applied Bending Stress (N/mm^2)	Permissible Bending Stress (N/mm^2)	Ratio of Applied to Permissible Bending Stress.
1	Double howe	3.69	11.869	0.311
2	Mono pitch	12.202	11.869	1.028
3	Stub	11.226	11.869	0.946
4	Cathedral	9.254	11.869	0.78
5	Sloping flat	8.064	11.869	0.679
6	Polynesian	9.627	11.869	0.811
7	Hip	24.281	11.869	2.046
8	Gambrel	9.556	11.869	0.805
9	Attic	1.989	11.869	0.168
10	Flat	3.393	11.869	0.286

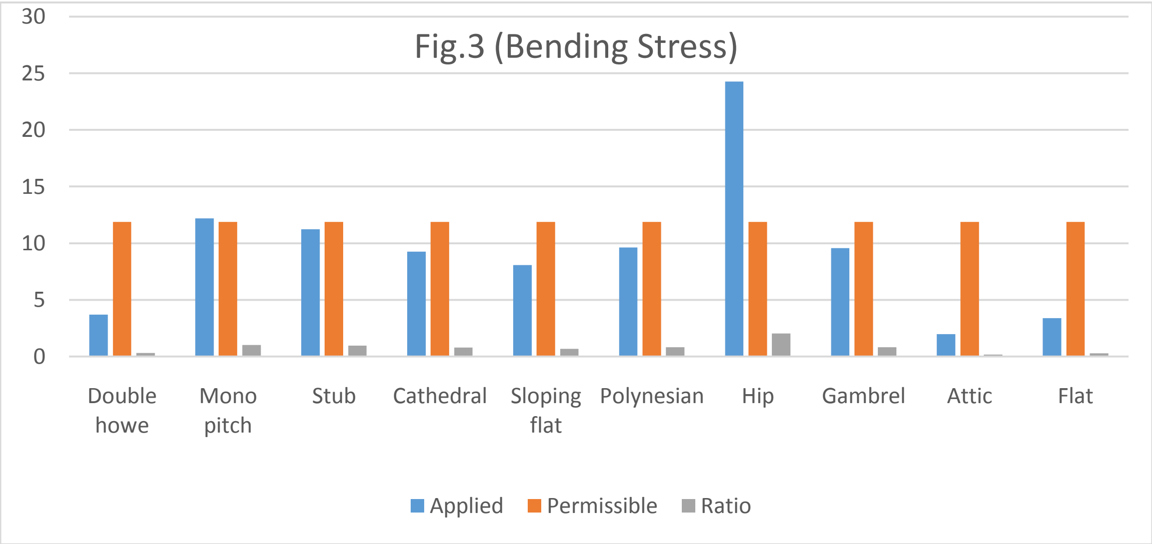


Table 4: Shear stress values

S/N	Truss Type	Applied Shear Stress (N/mm^2)	Permissible Shear Stress (N/mm^2)	Ratio of Applied to Permissible Shear Stress.
1	Double howe	0.359	1.1	0.326
2	Mono pitch	0.452	1.1	0.411
3	Stub	0.443	1.1	0.403
4	Cathedral	0.367	1.1	0.334
5	Sloping flat	0.343	1.1	0.312
6	Polynesian	0.408	1.1	0.371
7	Hip	0.659	1.1	0.599
8	Gambrel	0.383	1.1	0.348
9	Attic	0.18	1.1	0.164
10	Flat	0.233	1.1	0.212

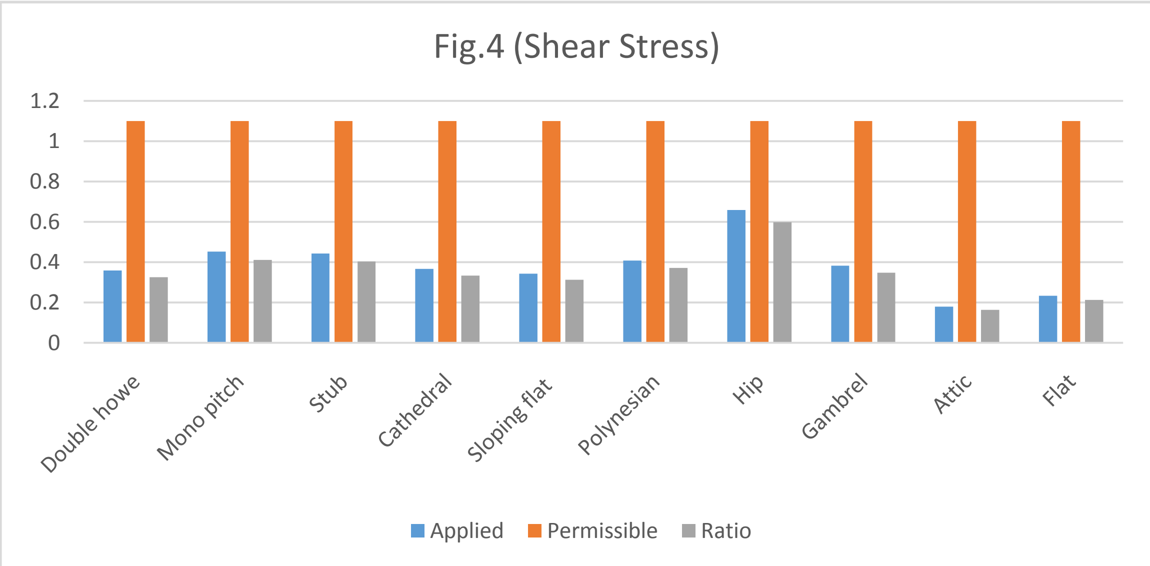


Table 5: Average stress ratio values

S/N	Truss Type	Average stress ratio
1	Double howe	0.332
	Mono pitch	0.449
3	Stub	0.551
4	Cathedral	0.434
5	Sloping flat	0.551
6	Polynesian	0.443
7	Hip	0.874
8	Gambrel	0.377
9	Attic	0.34
10	Flat	0.259

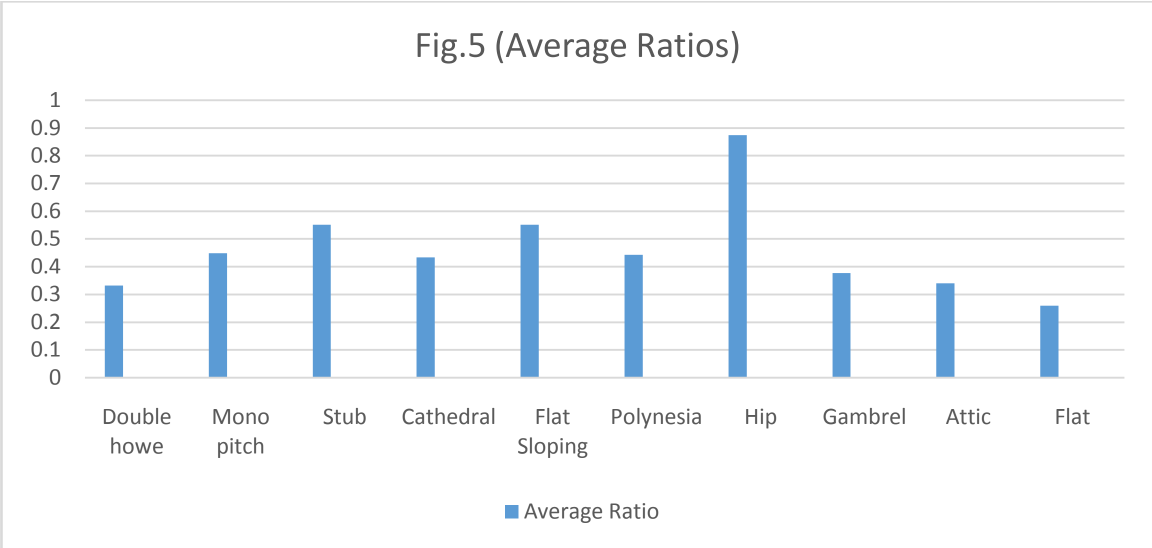


Fig.1 is the chart of the applied, permissible and ratio of the applied to permissible of the tensile stresses of the ten different trusses plotted with values from table 1. From the chart, it is seen that mono pitch truss has the lowest applied tensile stress and also the lowest applied to permissible tensile stress ratio (1.131N/mm^2 and 0.154 respectively). The truss with the highest applied stress is the attic truss with values of applied and ratio of applied to permissible tensile stress of 4.113N/mm^2 and 0.561 respectively.

Fig.2 is the chart of the applied, permissible and ratio of the applied to permissible of the compressive stresses of the trusses. From table 2, it can be seen that the truss with the lowest applied compressive stress is the gambrel truss with values of applied, and ratio of applied to permissible of 1.116N/mm^2 and 0.183 respectively. The truss with the highest values of applied and ratio of applied to permissible compressive stress is the sloping flat truss with values of 4.578N/mm^2 and 0.665 respectively.

Fig.3 is the chart of the applied, permissible and ration of the applied to permissible of the bending stresses of the trusses. The attic truss has the lowest applied, and applied to permissible bending stress ratio values which are 1.989N/mm^2 and 0.168 (from table 5.3) respectively. The hip truss has the highest applied, and applied to permissible stress ratio which are 24.281N/mm^2 and 2.046 respectively. The hip truss and mono pitch trusses have applied to permissible stress ratios greater than unity, hence do not satisfy bending requirement using this section.

Fig.4 is the chart of the applied, permissible and ratio of the applied to permissible of the shear stresses of the trusses and is plotted from values in table 4). The truss with the lowest applied, and ratio of applied to permissible shear stress is the attic truss with values of 0.18N/mm^2 and 0.164 respectively, while the truss with the applied, and ratio of applied to permissible shear stress is the attic truss with values of 0.659N/mm^2 and 0.559 respectively.

Fig.5 is the chart of the chat of the average applied to permissible stress ratios of the trusses. From table 5, it can be deduced that the flat truss has the lowest applied to permissible ratio value which is 0.259, followed by the double howe truss with 0.333. The hip truss has the highest value which is 0.874, and is followed by the stub and flat sloping trusses with a value of 0.551 each.

VII. CONCLUSION

In conclusion, the truss arrangement of the truss types according to their structural adequacy in terms of compressive stress from highest to lowest is; Mono pitch > gambrel > Polynesian > flat > cathedral > stub > double howe > hip > sloping flat > attic. Mono pitch is the most adequate while attic is the least adequate in terms of tensile stress adequacy. This means that the mono pitch truss is less likely to fail due to compression among the ten trusses designed, while the attic truss is the most likely to fail by tension.

The arrangement of the truss types from highest to lowest with respect to their compressive adequacy is; Gambrel > mono pitch > flat > double howe > Polynesian > attic > cathedral > hip > stub > sloping flat. The most adequate in terms of compression being gambrel while the least adequate being sloping flat.

The arrangement of the trusses in order of reducing bending adequacy is; Attic > flat > double howe > sloping flat > cathedral > gambrel > Polynesian > stub > mono pitch > hip. The most adequate in bending resistance being the attic truss while the least adequate is the hip truss.

The arrangement of the trusses in order of decreasing structural adequacy in terms of shear stress resistance is given by; attic > flat > sloping flat > double howe > cathedral > gambrel > Polynesian > stub > mono pitch > hip.

When the tensile, compressive, bending and shear stresses are all considered, the order of decreasing structural adequacy of the trusses are; flat > double howe > attic > cathedral > gambrel > Polynesian > mono pitch > stub, sloping flat > hip. The flat truss being the most structurally adequate generally while the hip truss is the least.

VIII. RECOMMENDATION

In roofs prone to high tensile stress, the mono pitch truss is recommended for use as roof truss, followed by the gambrel truss. Attic and sloping flat trusses should be avoided in such situations.

For roofs susceptible to high compressive stress, gambrel truss is recommended for use as roof truss, followed by the mono pitch. In such condition, the hip and the sloping flat trusses should be avoided because of their poor performance in compression.

For roofs susceptible to high bending stress, the recommended truss type to be adopted is the attic truss, followed by the flat truss. The hip and mono pitch trusses should be avoided.

For roofs susceptible to high shear stress, the attic and the flat trusses are the best options to adopt. The hip and the mono pitch trusses should be avoided.

In terms of average performance in the various situations, the flat roof is the recommended truss type for adoption, followed by the double howe truss. In such condition, the hip and the sloping flat truss types should be avoided.

Hence, for conditions where the imposed load on the roof truss is high due to high wind pressure, snow or heavy down pour, the recommended roof trusses for use are the attic truss, mono-pitch truss, the gambrel truss and the flat truss. If the flat truss is to be adopted, adequate drainage properties must be incorporated in the roof design.

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