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ANALYSIS OF EXTENDABLE IBS STEEL TRUSS

LIEW VUI JEN

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Civil-Structure)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JUNE 2008

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To my beloved mother, father and brothers for their never ending care and support.

To all my friends, thank you for everything.

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ABSTRACT

Steel truss is a very common structure in construction. Many roofs are constructed by using steel trusses due to the high strength and durability of steel relative with its weight and size. Many types of steel trusses were also found to be commonly used. In this study, some common types of steel trusses are compared against their strength and weight, or described as their effectiveness in load sustaining. The type of truss that is most cost effective is then being used as the model to check for the capability of different sections such as hollow section, angle and channels. The section properties of these members are studied and being used in the analysis to obtain the sections that is most effective for being members in an extendable steel truss. After the most suitable member for the steel truss is found, a scaled model of truss is fabricated by using timber to study the extendability of the truss. The extendable or deployable truss is aimed to fit a span from 5.49 m to 8.53 m with an incremental of 0.6 m. This span is aimed to fit the normal width of a residential Industrial Building System (IBS) house. The pitch of the steel truss is controlled so that a minimum roof pitch is maintained to allow for the rain fall. Another scaled model is fabricated to fit longer width of a normal residential house, from 8.53 m to 13.72 m with an incremental of 0.6 m each. These extendable trusses are fabricated with standardized components towards IBS. The joints of the truss are also being studied to observe the joint failure for the expendable. Finally, the deflection, weight and sizes for both of the extendable trusses are determined. The bolt to connect the truss members is also designed in compliance with BS 5950.

ABSTRAK

Kerangka kekuda besi adalah struktur yang biasa digunakan untuk mendirikan bumbung rumah disebabkan oleh kelasakannya. Banyak jenis kerangka kekuda telah digunakan untuk mendirikan bumbung. Dalam kajian ini, jenis-jenis kerangka kekuda telah dibandingkan supaya kerangka kekuda yang paling ringan dan efektif untuk pesongan. Selain itu, seksyen-seksyen untuk membina kerangka kekuda juga telah dibandingkan supaya seksyen yang paling menjimatkan dapat dicari. Selepas itu, sebuah kerangka kekuda yang berskala dibuat untuk menganalisis kebolehpanjangan kerangka kekuda ini. Kerangka kekuda ini dibuat supaya boleh memanjang dari 5.49m kepada 8.53m dengan 0.6m setiap kali memanjang. Rentang kerangka kekuda ini boleh digunakan untuk lebar rumah teres yang biasa didirikan. Kecondongan kerangka kekuda ini juga dikawal supaya kecondongan itu cukup untuk air hujan mengalir dan mengelakkan takungan air di atas bumbung rumah. Selain itu, sebuah kerangka kekuda berskala lain yang berlainan rentang juga telah dibina. Kerangka kekuda ini dibuat supaya boleh memanjang dari 8.53m kepada 13.72m dengan 0.6m setiap kali memanjang. Komponen-komponen kerangka kekuda ini dibuat dengan komponen-komponen yang seiring menuju ke arah Sistem Bangunan Industri (IBS). Di samping itu, sambungan kerangka kekuda ini juga dikaji supaya sambungan yang tegar boleh dibuat. Akhirnya, berat, saiz seksyen dan pemesongan kerangka kekuda ini dicari dengan program computer Staad-Pro. Saiz bolt untuk menyambung kerangka kekuda juga disemak dengan piawaian BS 5950.

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LIST OF ABBREVIATIONS

AISC	American Institute of Steel Construction Inc.
BS	British Standard
BSI	British Standard Institution
CIB	Conseil International Batiment
EC3	Eurocode 3
IBS	Industrial Building System
RHS	Rectangular Hollow Section

LIST OF SYMBOLS

A_e	-	Effective sectional Area
A_{eff}	-	The area of the effective cross section
A_g	-	Gross sectional Area
A_s	-	Shear area
a_1	-	Net sectional area of the connected leg
a_2	-	Net sectional area of the unconnected leg
d	-	The nominal diameter of the bolt
e	-	End distance from edge to center of bolt
f_c	-	The compressive strength
I	-	The radius of gyration about the relevant axis, determined using the properties of the gross cross section
L	-	Node to node length perpendicular to W
L_E	-	Effective length of the strut about the appropriate axis
L	-	The buckling length, conservatively taken as equal to the system length L provided that both ends are held in position laterally
M_b	-	Lateral torsional buckling resistance
M_{cy}	-	The moment capacity about the y axis
m_x	-	Equivalent uniform moment factor at x axis
m_y	-	Equivalent uniform moment factor at y axis
$N_{b.Rd}$	-	The design buckling resistance of the member
$N_{c.Rd}$	-	The design compression resistance of the cross section
$N_{pl.Rd}$	-	The design plastic resistance of the gross section
N_{Sd}	-	Design value of the tensile force
$N_{t.Rd}$	-	Design tension resistance of the cross section

$N_{u.Rd}$	-	The design ultimate resistance of the net section at bolt holes
P_{bb}	-	The bearing capacity of the bolt
P_{bs}	-	The bearing capacity of the connection part
P_c	-	Members' compression resistance
P_s	-	Shear capacity of bolts
P_t	-	Members' tension capacity
p_b	-	Bending Strength
p_{bb}	-	The bearing strength of the bolt
p_{bs}	-	The bearing strength of the connection part
p_s	-	Shear strength of the bolt
p'_c	-	Compressive strength based on a reduced design strength
λ	-	Slenderness of a compression member
r	-	The radius of gyration about the appropriate axis
S	-	Plastic modulus
t_p	-	The thickness of the connected part
W	-	Purlin Load

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CHAPTER 1

INTRODUCTION

1.1 Introduction

A roof is the covering on the uppermost part of a building. Roof is considered as a small part of a building, but it plays a very important role. The purpose of a roof is to protect the building and its contents from the effects of weather, loading such as rain and wind, heat, for aesthetics view, for safety concerns and so on. The types of structures that require roofs range from the size of a letter box to that of a cathedral or stadium, dwellings being the most numerous.

The characteristics of a roof are dependent upon the purpose of the building that it covers. The available roofing materials and the local traditions of construction maybe governed by local or national legislation.

In most countries a roof protects primarily against rain. Depending upon the nature of the building, the roof may also protect against heat, against sunlight, against cold and against wind. If the roof is the covering for a house, then all these protective functions are called into play. Other types of structure, for example, a garden conservatory, might utilize roofing that protects against cold, wind and rain but admits light.

The weather proofing material is the topmost or outermost layer, exposed to the weather. Many different kinds of materials have been used as weather proofing material such as tile, wood, zinc, steel, concrete and fabric.

Galvanized steel frequently manufactured with wavy corrugations to resist lateral flexing and fitted with exposed fasteners. Widely used for low cost and durability. It was the most extensively used roofing material of 20th century.

Trusses form by steel sections is normally being constructed to support the galvanized steel roofing and tile. Various types of steel trusses have been invented and used such as Warren, King Post, Storage, Scissors, Fink, Fan and others.

These trusses are selected based on many criteria before being constructed and lifted onto the building. They are considered among their usage, cost, span, space and so on.

1.2 Problem Statement

Steel trusses are normally being constructed on site and lifted onto the buildings. This will normally take a lot of time and labours to cut the steel section, weld or bolt the section together and apply protection coatings.

The qualities and quantities of the trusses are not controlled well on site. Besides, many steel sections are wasted due to incorrect measurement and skills. The trusses form can only be used for a specific building as the size of the trusses is fixed. Thus, when a different size of truss is required, another size of truss has to be design and constructed to fix the requirement. This will longer the construction period of a structure and directly increases the cost for the project.

1.3 Objective

a) Compare the various types of trusses for strength, durability and weight

b) Deployable or extendable truss to fit an incremental span for a normal IBS house

c) Standardized components for a truss to fit an incremental span for a normal house usage

1.4 Scope Of Study

First of all study of the shapes of the roof truss is carried out on some of the common roof trusses that found nowadays. Analysis is carried out by using computer aided programme, Staad-Pro to obtained the lightest but larger strength's shape for the roof truss.

Besides shapes, the section properties of the roof truss members are also being analyzed to find the most efficient sections to be used for roof truss. Rectangular hollow section (RHS), angle and C channels are being compared in the analysis. Only galvanized mild steel section is being considered due to the strength and durability of steel in construction. Besides strength, the flexibility of the sections in connection is also important.

The study is being carried out by analyze the steel trusses using Staad-Pro to check the strength, durability and weight of the selected trusses. Then, comparisons are made between the trusses for their weight, strength, durability and materials.

The most effective and lightest truss is being used to develop a deployable or extendable truss to fit the various span of a house. This deployable truss should be able to extend from a shorter span to a longer span with an acceptable fall degree.

The build ability of the selected truss is also taken into consideration in this study. It is important that the truss selected is easily fabricated without difficult components. Beside, the time to build the truss is also being considered as this is also another governing factor.

An engineered scaled truss is modeled to analyze the abilities, joint and strength of the extendable or deployable truss. This truss is done by timber to ease fabrication and modifying jobs. The extendable or deployable truss is aimed to fit a span from 5.49 m to 8.53 m with a step of 0.6 m each. This span is aimed to fit the normal width of a residential Industrial Building System (IBS) house. The pitch of the steel truss is controlled so that a minimum roof pitch is maintained to allow for the rain fall.

Another scaled model is fabricated to fit longer width of a normal residential house, from 8.53 m to 13.72 m with a step of 0.6 m each. These extendable trusses are fabricated with standardized components towards IBS.

After that, the deflections, weight and sections of the trusses for every span is obtained by using Staad-Pro. Bolt connection to joint the members together is also check in compliance with BS 5950 with the maximum forces obtained from Staad-Pro analysis on the trusses.

1.5 Significant Of The Study

This study is aimed to find out the most cost effective type of truss to be used in construction field as this will save a lot of extra cost. Besides, the most effective materials to be used is also important to the construction field. The study is also aimed to develop an extendable or deployable truss to fit the various span required. This will not only benefit from the construction time, it also enable to reduce construction cost and labour needed if it is being produced at large scale.

1.6 Expected Findings

Warren truss is expected to be the most effective type of truss compared to others. This may due to lesser vertical chords in warren truss. RHS should be the most effective sections to be adopted in truss due to its geometry.

Scaled truss models which can be extended in a given range maybe developed. The truss can be extended to fit some incremental length and maintained the roof pitch to allow for rain water drainage.

Standardized section sizes and components are to be selected to be used as the members for the trusses to ease the fabrication which fulfill the Industrial Building System (IBS).

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

There are many studies on how to produce structures with optimized materials, cost and labour but stronger, more durable and even environmental friendly. Thus, topic such as sustainable development is arose quickly in this few decades.

2.2 Sustainability

Unprecedented forces are reshaping the building construction industry, forcing professionals engaged in all phases of building construction, design, operation, financing, insurance and public policy to fundamentally rethink their roles in the building delivery process. The main impetus is the sustainable development movement, which is changing not only physical structures but also the working of the companies and organizations that populate the building environment, as well as the hearts and minds of individuals who inhabit it. (Lester, 1992)

The sustainable development movement has been evolving worldwide for almost two decades, causing significant changes in building delivery systems in a relatively short period of time. A subset of sustainable development, sustainable construction addresses the role of building environment in contributing to the overarching vision of sustainability. (Kibert, 2005)

In 1994, the Conseil International Batiment (CIB), an international construction research networking organization defined the goal of sustainable construction as ‘ creating and operating a healthy built environment based on resource efficiency and ecological design’. Figure 2.1 follows shows the framework for sustainable construction developed in 1994 by CIB.

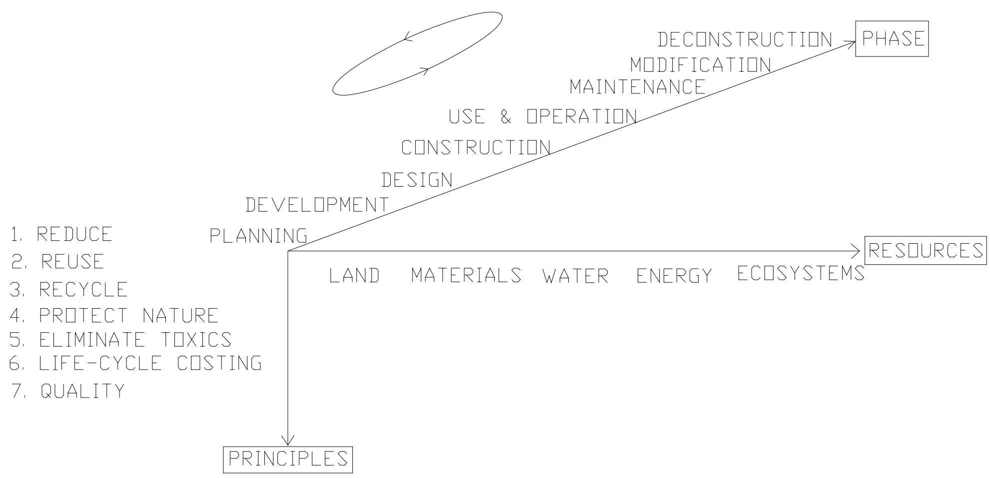

Figure 2.1 : Framework for sustainable construction (Kibert, 2005)

The term high performance, green and sustainable construction are often used interchangeably, however it is the term sustainable construction that most comprehensively addresses the ecological, social and economic issues of a building in the context of its community.

Sustainability is a characteristic of a process or state that can be maintained at a certain level indefinitely. The term, in its environmental usage, refers to the potential longevity of vital human ecological support systems, such as the planet's climatic system, systems of agriculture, industry, forestry, and fisheries, and human communities in general and the various systems on which they depend in balance with the impacts of our unsustainable or sustainable design. (Kibert, 2005)

In recent years an academic and public discourse has led to this use of the word sustainability in reference to how long human ecological systems can be expected to be usefully productive. In the past, complex human societies have died out, sometimes as a result of their own growth-associated impacts on ecological support systems. The implication is that modern industrial society, which continues to grow in scale and complexity, will also collapse.

The implied preference would be for systems to be productive indefinitely, or be "sustainable." For example, "sustainable agriculture" would develop agricultural systems to last indefinitely; "sustainable development" can be a development of economic systems that last indefinitely, etc.

Besides, safety in another concern for sustainable construction as nowadays many accidents occurs at construction site due to the conventional construction method. Thus, but developing sustainable construction the number of accidents is aimed to be reduced.

Due to the drastic changes in economy of the world nowadays, many changes of purposes on buildings have been applied, for example from warehouses to factories, houses to shops, residential apartments to hotels and so on. Thus, the development of sustainable construction is trying to produce products with lesser changes of structure when the purposes of the products are being modified.

2.2.1 Sustainable Technology

Sustainable technologies are technologies which use less energy, fewer limited resources, do not deplete natural resources, do not directly or indirectly pollute the environment, and can be reused or recycled at the end of their useful life. There is a significant overlap with appropriate technology, which emphasizes the suitability of technology to the context, in particular considering the needs of people in developing countries. However, the most appropriate technology may not be the most sustainable one; and a sustainable technology may have high cost or maintenance requirements that make it unsuitable as an "appropriate technology," as that term is commonly used.

2.2.2 Sustainable Design

Sustainable design is the art of designing physical objects and the built environment to comply with the principles of economic, social, and ecological sustainability. It ranges from the microcosm of designing small objects for everyday use, through to the macrocosm of designing buildings, cities, and the earth's physical surface. It is a growing trend within the fields of architecture, landscape architecture, urban design, urban planning, engineering, graphic design, industrial design, interior design and fashion design.

The needed aim of sustainable design is to produce places, products and services in a way that reduces use of non-renewable resources, minimizes environmental impact, and relates people with the natural environment. Sustainable design is often viewed as a necessary tool for achieving sustainability.

Thus, architects are being responsive to develop products that fulfill sustainable construction will creativity as the term sustainability is still not common among each others. Structural engineers also play a very important role in developing sustainable constructions for the structures. They have to design the structures and consider many aspects of the structures by relating them with the term sustainability for example safety, less materials and energy, environmental friendly and so on. Figure 2.2 follows shows the interaction between many sides to reach for the sustainable construction.

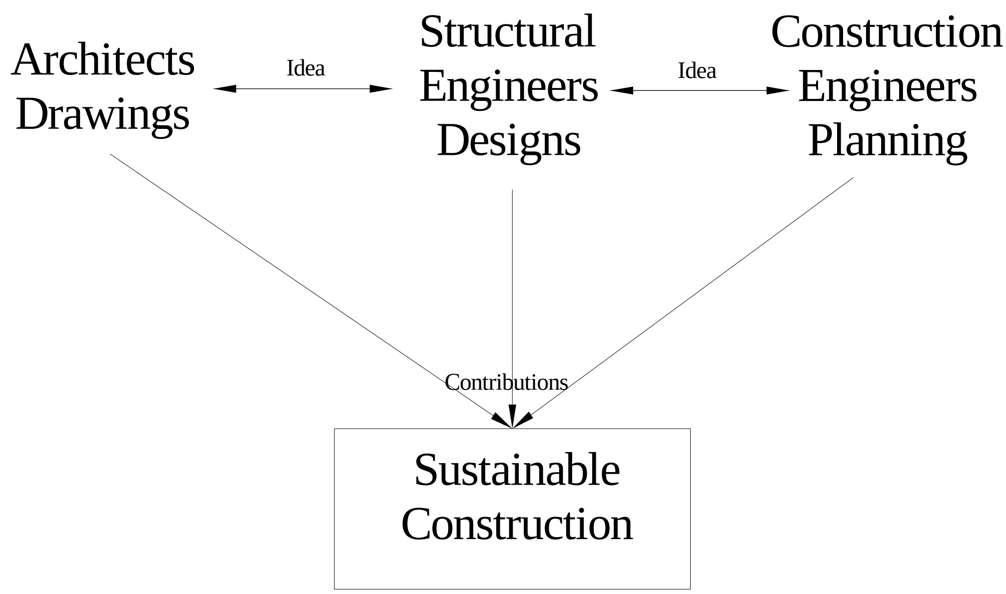

Figure 2.2 : Idea and contributions from all of the parties are needed for a good sustainable construction

2.2.3 Sustainability in Construction

Sustainable Construction aims to apply this principle to the construction industry by providing ways of buildings that use less virgin material and less energy, cause less pollution and less waste but still provide the benefits that construction projects have brought us throughout history.

In this case study the sustainability considered is to developed a roof truss that can suit a range of span for houses. By using this kind of truss there are many benefits than can be generated which achieve the sustainability in constructions, such as energy efficiency, wastes reduction and time saving.