UNIVERSITI PUTRA MALAYSIA

SATRUCTURAL STRENGTH AND BEHAVIOUR OF CYLINDRICAL STEEL SHEET ROOFING

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STRUCTURAL STRENGTH AND BEHAVIOUR OF CYLINDRICAL STEEL SHEET ROOFING

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

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Specially Dedicated to My Father Md. Azizul Haque, Mother MST. Rowsanara and Wife MST. Masuma Khatun

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Masters of Science

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CHAIRMAN: PROFESSOR ABANG ABDULLAH ABANG ALI

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The roof does not only protect the building and its occupants from the effects of weather, but it is also an architectural feature that gives the building a desired appearance. Profiled steel sheet zincalume is normally used in roof as covering materials, without any attention paid to its structural capability as a self-supporting medium. A self-supporting roofing element is a new; where profiled sheeting roof could run continuous lengths of roof spans without internal support. This roofing system saves material and construction cost by avoiding internal support.

The aim of this research work is to study the possibility of using profiled steel sheet as self-supporting roofing elements for affordable housing. An analytical investigation using the finite element method was carried out on the structural strength and behaviour of different types of self-supporting roofing elements. Five laboratory tests using 3 m spans, 0.42 mm thickness and different crown heights of 1.5, 1.0, 0.50, 0.25 and 0.125 m specimens were conducted for assessing the structural strength and behaviour of roofing elements. Analytical study was carried out on the effect of shape, size, materials and support condition on the structural

behaviour of the selected roofing element. The analytical investigation was extended for longer spans to explore the feasibility of using of profiled steel sheet as a self-supporting roofing system in housing construction. In the analytical work, finite element models were generated and analyzed by using LUSAS software.

The analytical study for the roofing elements showed that parabolic profiled roofing element with crown height 1/6 of span length was more efficient than others as a self-supporting element. The proposed self-supporting roofing element satisfied geometrical, buckling and material stability. Deflection was found to be the limiting criteria in design for self-supporting roofing element using profiled steel sheet. The presence of corrugation in the steel roofing element resulted in a significant improvement on the roof's structural performance compared to flat sheet element. Good agreement was found between the results from finite element analysis and those obtained experimentally. The FEM models predicted with a reasonable degree of accuracy the structural behaviour of different types of roofing elements. It was observed that a parabolic shape roofing element with an optimum crown height could be used as a self- supporting roofing element for about 4 m and 8 m span lengths using 0.42 mm and 1.25 mm thick profiled steel sheet. On the basis of this investigation, parabolic self-supporting roofing elements using profiled steel sheet with optimum crown height could be used in housing construction.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memennuhi keperluan untuk ijazah Master Sains

KEKUATAN STRUKTUR DAN KELAKUAN UNTUK BUMBUNG KEPINGAN KELULI SILINDER

OLEH

S. M. ZAHURUL ISLAM

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Penutup bumbung bukan sahaja dapat melindungi bangunan dan penghuninya dari kesan cuaca tetapi ia juga menberi bentuk senibina yang dihendaki. Secara umumnya, kepingan besi beralun seperti zincalume digunakan sebagai bahan penutup tanpa mengambil kira kebolehan strukturnya untuk sokongan tersendiri. Elemen bumbung sokongan tersendiri terdiri daripada kepingan bumbung-bumbung yang dipasang tanpa sokongan dalam. Bumbung ini menjimatkan kos bahan dan pembinaan tanpa struktur sokongan dalaman.

Objektif utama penyelidikan ini ialah untuk membangunkan sistem bumbung yang mempunyai penyokong tersendiri untuk rumah kos rendah. Kajian secara analitik menggunakan kaedah unsur terhingga telah dijalankan ke atas kekuatan struktur dan kelakuan pelbagai jenis bumbung sokongan tersendiri. Lima ujian experimen telah dijalankan untuk menggunakan jarak 3 m, ketebalan 0.42 mm dan ketinggian 1.5, 1.0, 0.5, 0.25 dan 0.125 mm untuk merilai kekuatan struktur dan kelakuan elemen penutup bumbung. Kajian analitikal secara terperinci telah dijalankan ke atas kesan bentuk, saiz, bahan-bahan dan keadaan penyokong untuk kekuatan struktur dan sifat-sifat elemen bumbung yang dipilih. Kajian analitikal telah dijalankan bagi jarak yang

lebih besar untuk menentukan kebolehan kepingan besi beralun sebagai bumbung sokongan di dalam pembinaan perumahan. Di dalam ujikaji analitikal ini, model unsur terhingga telah dijalankan dan dianalisis oleh perisian LUSAS.

Kajian analitikal untuk elemen bumbung berbentuk parabola dengan ketinggian puncak 1/6 daripada jarak panjang didapati lebih effisien berbanding dengan yang lain sebagai unsur sokongan tersendiri. Bumbung sokongan tersendiri telah memenuhi kestabila geometric, buckling dan bahan. Pesongan telah didapati menjadi had rekabentuk bumbung sokongan tersendiri bagi kepingan besi beralun. Kehadiran bentuk beralun di dalam binaan elemen bumbung memberi kesan yang signifikan ke atas kekuatan struktur berbanding dengan elemen bumbung rata. Keputusan daripada analisis unsur terhingga adalah selaras dengan keputusan daripada makmal ujikaji. Model FEM menghasilkan jangkaan dengan kejituan yang tinggi terhadap sifat-sifat struktur pelbagai jenis elemen penutup bumbung. Keputusan menunjukkan bahawa elemen bumbung berbentuk parabola dengan ketinggian optimum boleh digunakan sebagai elemen bumbung sokongan tersendiri bagai jarak kepanjangann 4m hingga 8m dengan menggunakan 0.42 mm dan 1.25 mm tebal besi beralun. Hasil kajian mendapati bahawa elemen bumbung zincalume beralun sokongan tersendiri yang berbentuk parabolia dengan ketinggian lurah optimum boleh digunakan di dalam pembinaan perumahan.

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N_x	Membrane internal force along x direction
N_y	Membrane internal force along y direction
N_{xy} & N_{xy}	Membrane internal force along xy Plane
M_x	Bending moment about x axis
M_y	Bending moment about y axis
M_{xy}	Twisting moment along xy plane
Q_x	Plane shear force about x axis
Q_y	Plane shear force about y axis
M_{yy}	Bending moment about yy axis
I_{yy}	Second moment of inertia
Q	First moment of inertia
Z	Centroid of circular cylindrical shell
W / UDL	Uniformly distributed load
g	Self weight
u	Displacement along x direction
v	Displacement along y direction
w	Displacement along z direction
J	Jacobian matrix
ε	Membrane Strain components
B_f	Strain matrix
Π	Potential energy
D	Flexural and shear rigidities matrix
K	Stiffness matrix
N	Membrane stress resultants
M	Flexural stress resultants
Γ	Flexural strain
$\psi_x, \psi y, \psi xy,$	Flexural strain in the local Cartesian system
E	Modulus of elasticity
υ	Poisons ratio
t	Thickness of materials
GIS	Galvanized iron sheets

CHAPTER 1

INTRODUCTION

1.1 Background

The housing need in Malaysia is ever increasing due to rapid industrialization, urbanization, development and population explosion. Hence there is a growing awareness throughout the country among scientists, engineers, builders, designers and architects as well as developers to develop suitable low cost housing designs and bring down the cost of construction. The shortage of houses can be reduced to a greater extent by adopting new or alternative building materials or innovative construction techniques using conventional building materials. Due to the inadequacy of traditional building construction approach, new building systems started to appear at the beginning of the 20th century. Industrialised Building System (IBS) could provide a solution to the many problems in construction especially since the buildings constructed using this alternative method of construction have a shorter construction time and labour saving. The country is therefore looking for suitable alternatives to the conventional building approach to provide affordable quality housing to its citizens. Various programmes have been introduced to increase the housing stock in every country of the world, but the solution to the provision of affordable housing in sufficient quantity and quality for low–income strata of society has eluded many governments (Abang, 1994). Affordability is a term used to describe the relationship between income and effective demand of commodity. A "quality house" is one whereby the residents are happy and satisfied to live in while an "affordable house" is one, which do not create financial problems to the house owner.