INFLUENCE OF ROOF SHAPE ON THE NATURAL VENTILATION POTENTIAL OF A BUILDING

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DECLARATION

I declare that this report entitled "Influence of Roof Shape on the Natural Ventilation Potential of a Building" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	_______________________
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SUPERVISOR'S DECLARATION

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Honours.

Signature	:	______________________
Supervisor	:	DR. CHENG SEE YUAN
Date	:	______________________

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DEDICATION

To my beloved mother and father

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ABSTRACT

The present study investigated the influence of different roof shapes on the natural ventilation potential of an isolated low-rise building by using Computational Fluid Dynamics (CFD). The Barrel Vault, Gable, Pyramid and Shed roof were chosen for the study. The Realizable k-ε turbulent model was adopted in the CFD simulations. The wind which obeyed power law equation was set to approach the building model at eight different angles. The natural ventilation potential of the ground and the upper floors of the building model were studied separately with the assumption of no cross ventilation between both floors. The Shed roof shape was found out to be the highest performer in inducing natural ventilation, the Barrel Vault roof came in second, followed by the Gable roof and lastly, the Pyramid roof. It was proven that different roof shapes will have significant influence on the natural ventilation potential of a building.

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ABSTRAK

Kajian ini mengkaji pengaruh bentuk bumbung yang berbeza kepada potensi pengudaraan semula jadi sesebuah bangunan dengan menggunakan Dinamik Bendalir Berkomputer. Bumbung “Barrel Vault”, “Gable”, “Pyramid” dan “Shed” telah dipilih sebagai bentuk kajian. Model bergelora “Realizable k-ε” telah digunakan dalam simulasi Dinamik Bendalir Berkomputer. Angin yang berdassarkan formula “power law” telah ditetapkan untuk menuju ke bangunan modal dari lapan arah yang berbeza. Potensi pengudaraan semula jadi bagi aras bawah dan aras atas telah dikaji secara berasingan dengan andaian tiada pengudaraan salib antara kedua-dua aras. Bentuk bumbung “Shed” didapati mencapai potensi pengudaraan semula jadi yang tertinggi, bentuk bumbung “Barrel Vault” mencapai tempat kedua, diikuti bentuk bumbung “Gable” dan akhir sekali, bentuk bumbung “Pyramid”. Kajian ini tela membuktikan bahawa bentuk bumbung yang berbesa akan mempengaruhi potensi pengudaraan semula jadi sesebuah bangunan.

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LIST OF ABBREVIATIONS

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CFD	Computational Fluid Dynamics
IAQ	Indoor Air Quality
RAM	Random Access Memory
RNG	Re-Normalisation Group
SBS	Sick Building Syndrome
SFP	Split Fibre Probe
SST	Shear Stress Transport
UDF	User-Defined Function

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LIST OF SYMBOLS

$Q_{buoyancy}$	=	Buoyancy ventilation rate
Cd	=	Discharge coefficient
A	=	Cross sectional area of the inlet that equals to the outlet
g	=	The acceleration due to gravity
h	=	Vertical distance between inlet and outlet midpoints
T_i	=	Average temperature of indoor air
T_o	=	Average temperature of outdoor air
$Q_{ventilation}$	=	wind driven ventilation rate
U_{wind}	=	wind speed at far-field
C_{p1}	=	coefficient of wind pressure drag at the upstream opening
C_{p2}	=	coefficient of wind pressure drag at the upstream opening
A_1	=	cross sectional area of the inlet
A_2	=	cross sectional area of the outlet
C_1	=	discharge coefficient at the inlet
C_2	=	discharge coefficient at the outlet
ΔP	=	Pressure drop across the openings
ρ	=	Air density
P	=	Pressure measured on the building surface
C_p	=	Pressure coefficient
U	=	Air velocity

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Re	=	Reynolds number
u	=	Fluid velocity
L	=	Characteristic linear dimension
μ	=	Dynamic viscosity of the fluid
ν	=	Kinematic viscosity of the fluid
H_e	=	Building height
Hz	=	Hertz
k	=	Turbulent kinetic energy
ε	=	Epsilon
ω	=	Omega
U_1	=	Streamwise velocity
U_{He}	=	Air velocity at building height
W	=	Building width
k_s	=	Roughness height
C_s	=	Roughness constant
Z_0	=	Aerodynamic roughness length of the topography
°	=	Degree
x/He	=	Ratio of unit length in x-axis against height of the building model
C_{diff}	=	Difference in Coefficient of Wind Pressure

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Ventilation is a process of air circulation or exchange of air into and out of a space. In a tropical country like Malaysia, ventilation plays an important role in good indoor air quality (IAQ) of a building. Adequate air ventilation provide thermal comfort in a building and at the same time reduce the possibility of Sick Building Syndrome (SBS) among the residents (Norhidayah et al, 2013). According to an estimation by Spiru and Simona (2017), people in urban areas tend to spend up to 90% of their time in indoor environments especially work place. Hence, ventilation is crucial to ensure human wellbeing in a building.

There are essentially two types of ventilation: natural ventilation and mechanical ventilation. Natural ventilation usually involves wind while mechanical ventilation involves machines like fans and air conditioners. Mechanical ventilation systems force the air moves in the designated motion to provide ventilation or manipulating the temperature of air by certain degree. On the other hand, formation of natural ventilation relies heavily on air velocity and air flow pressure difference (Burnett et al, 2005). For cases where only insignificant indoor and outdoor temperature difference occur, air flow pressure difference determines the performance of natural ventilation (Cheng, 2007). As one of the aspects of building design, roof shape can create air flow pressure difference and thus affecting natural ventilation potential.

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Despite the convenience of mechanical ventilation system functions, it occupies more than half of the annual energy consumption in a building at a rate of 100kWh per square meter of floor space (Bastide, 2006). Over reliance on mechanical ventilation on a global scale will cause enormous amount of burden towards the environment and energy suppliers (Omrani et al, 2017). According to Schulze and Eicker (2013), several studies showed natural ventilation was able to save 17% of energy consumption by mechanical ventilation in a targeted building at Meiji University, Tokyo.

Studies done by Kubota and Ahmad (2006) shows that application of natural ventilation could build up thermal comfort in tropical climate conditions while improving indoor air quality as it removes hot polluted air in a building. Natural ventilation approach on a building design proved to be a cost and operation effective solution for higher indoor environment comfort (Lei et al, 2017). The advantages of natural ventilation has grabbed attention of architects as the future of building design is more aggressive on environmental friendly and energy saving approach.

Estate developers tend to focus more on aesthetic rather than functionality in their housing design to attract buyers. Usually, the natural ventilation potential of a building is not in the primary consideration of the buyers as they unknowingly compromise by utilizing mechanical ventilation systems that are widely available in the market. This behaviour may lead to unbalanced approach on both aesthetic and functionality aspects during building design process which directly interrupts the air flow pressure difference around the building.

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One of main factors found affecting the natural ventilation performance of a building in a study did by Aynsley (2007) was the building shape. The roof design has huge influence on air flow patterns around the building (Peren et al, 2015). Therefore, the intent of the project was to study the influence of roof shape on the natural ventilation potential on a building. The validation and verification of computational fluid dynamics (CFD) application were done by referring to a closely related work of Tominaga et al (2015). A few common roof shapes on typical low rise building were chosen as the target of investigation. Several vital parameters such as distribution of air pressure difference and air velocity on different roof shape designs were examined. The simulations were done on CFD capable software and data were extracted for further analysis on natural ventilation potential.

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