Faculty of Mechanical Engineering

A COMPUTATIONAL FLUID DYNAMICS (CFD) STUDY OF AN AIRFLOW IN A SINGLE STOREY BUILDING INTEGRATED WITH A COMBINED SYSTEM OF WIND CATCHER AND SOLAR CHIMNEY

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DECLARATION

I declare that this project entitled "A Computational Fluid Dynamics (CFD) study of an airflow in a single storey building integrated with a combined system of wind catcher and solar chimney" 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	:	....
Name	:	Mohammed Oudah Khalaf
Date	:	....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Mechanical Engineering (Energy Engineering).

Signature	:	....
Supervisor Name	:	Dr. Abdul Rafeq bin Saleman
Date	:	....

DEDICATION

I dedicate my project work to the sake of Allah, my Creator and my Master, My great teacher and messenger, Mohammed (May Allah bless and grant him), who taught us the purpose of life, my country Iraq ,my family and my friends. A special feeling of gratitude to my father, my mother, and my wife who encouraged me and a push for tenacity to improve myself throughout all my walks of life and who has always been with me in overcoming difficult times in my life. Patience is the meaning of love, kindness and gentle soul. Thank you for giving me a chance and I love them. I also dedicate this project to my siblings who have supported me through my life, I always miss and I cherish the memories that we had, I love all of you.

ABSTRACT

The biggest challenge in the 21st century is global warming, which seriously threatens humanity. The Building sector, which accounts for 40 % of global energy use and greenhouse gas emissions, plays a key role in this threat. In this regard, the effects of cooling systems can not be ignored if, together with ventilation and heating systems, they account for 60 % of the energy consumed in buildings. Passive cooling systems (natural ventilation) can be a promising alternative to reduce energy consumption, especially when using two natural ventilation systems combined together. However, there are little studies that look into the combined system between two types or more of natural ventilation systems. Therefore, this study looks into the design of the combined system of windcatcher and solarchimney for natural ventilation system with ground cooling system for a single storey building as a concept for natural ventilation system and evaluate the airflow of the system by using simulation of Computational Fluid Dynamics (CFD). The simulation models were run for different wind speeds (0.5, 1, and 1.5 m/s) and 303.15 K outdoor temperature. The simulation results obtained for the temperature distributions and the airflow patterns inside the room were presented with and without windcatcher, solarchimney and corrugate heat exchanger at different outdoor wind speed. The results shows that the temperature distribution in the room decreased by using catcher, solarchimney and corrugate heat exchanger. In addition, a greater temperature reduction was obtained by using the corrugated heat exchanger. The results obtained that the corrugated heat exchanger was able to reduce the temperature of the induced air stream while ensuring that the space was adequately ventilated. Moreover the results indicates that the air velocity distribution for the room increase with the increase of wind speed.

ABSTRAKT

Cabaran yang paling menonjol pada abad ke-21 adalah pemanasan global yang dengan seriusnya mengancam umat manusia. Sektor bangunan dengan 40 % penggunaan tenaga global dan pelepasan gas rumah hijau (GHG) memainkan peranan penting dalam ancaman ini. Dalam hal ini, kesan sistem penyejukan tidak boleh diabaikan di mana bersama-sama dengan sistem pengudaraan dan pemanasan ia menyumbang kepada 60 % tenaga yang digunakan dalam bangunan. Sistem penyejukan pasif (sistem pengudaraan semula jadi) boleh menjadi alternatif yang menjanjikan untuk mengurangkan penggunaan tenaga terutama jika digunakan dengan mengguna pakai dua sistem pengudaraan semula jadi dicantumkan antara satu sama lain. Di mana terdapat sedikit kajian yang melihat sistem gabungan antara dua jenis atau lebih sistem pengudaraan semula jadi. Oleh itu, kajian ini akan melihat reka bentuk sistem gabungan penangkap angin dan cerobong suria untuk sistem pengudaraan semula jadi dengan sistem penyejukan tanah untuk bangunan satu tingkat sebagai satu konsep untuk sistem pengudaraan semula jadi dan menilai aliran udara sistem dengan menggunakan perkomputeran dinamik bendalir (CFD). Model simulasi dijalankan untuk kelajuan angin yang berlainan (0.5, 1, dan 1.5 m / s) dan suhu luar pada 303.15 K. Hasil simulasi untuk pengagihan suhu dan corak aliran udara di dalam ruang bilik akan ditunjukkan dengan dan tanpa penangkap angin, cerobong suria dan penukar haba beralun pada kelajuan angin luar yang berlainan. Hasil keputusan, menunjukkan bahawa taburan suhu di dalam bilik menurun dengan menggunakan penangkap angin, cerobong suria dan penukar haba beralun. Tambahan pula, pengurangan suhu yang lebih besar diperolehi dengan menggunakan penukar haba beralun. Keputusan menunjukkan bahawa penukar haba beralun mampu mengurangkan suhu aliran udara terinduksi dan pada masa yang sama memastikan bahawa ruang bilik mendapat pengudaraan yang secukupnya. Selain itu, keputusan menunjukkan bahawa taburan halaju udara untuk bilik meningkat dengan peningkatan kelajuan angin.

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LIST OF ABBREVIATION

ABBREVIATIONS	DESCRIPTION
IEA	International Energy Agency
HVAC	Heating, ventilating, and air conditioning
USEPA	United States Environmental Protection Agency
SBS	Sick building syndrome
GHG	Greenhouse gas emissions
IAQ	Indoor air quality
HMT	Heat modulation techniques
LTS	lower temperature sinks
HDT	Heat dissipation techniques
PCM	Phase change material
MPM	Melting point materials
PVC	Polyvinyl chloride
SAV	Solar Accoustic Ventilation
EAHE	Earth air heat exchanger
CFD	Computational Fluid Dynamics
PDE	Partial Differential Equations
FVM	Finite Volume Method
GIT	Grid independence test

CHAPTER 1

INTRODUCTION

1.1 Background

In recent years due to the fast growth in world population leads to fast development of new buildings for residential, commercial and public buildings to cater the world population. The fast development of new buildings needs electricity, thermal comfort, water supply and improved indoor air quality and space-conditioning loads, cooling heating, and ventilation systems, lighting fixtures and appliances (Domich, P.D. et al., 2015). Thus it leads to high consumptions of energy. International Energy Agency (IEA) values that 40% of the global energy use is generated in residential, commercial and public buildings (Saadatian, O.et. al., 2012; Ghadirii, M.H. et. al., 2013). The energy consumption (40 %) with ventilation and heating systems amounts to a total of 60 % energy for the construction. In general, almost (60 %) of the energy consumption are coming from the air conditioning system or system for cooling of a building which is known as the thermal comfort of a building (Moosavi, L. et al., 2014; Hanif, M. et al., 2014). In fact, “Heating, Ventilation and Air Conditioning” (HVAC) are greatest energy users in the building (more than 60 %) in the building services sector, mainly from fossil resources (Manzano-Agugliaro, F. et al., 2015; Chenari, B. et. al., 2016). Such high consumption of energy is the main contributor to the global warming of the world. In this regard, the impact of thermal comfort system cannot be neglected (M. Mahdavinejad et al., 2012; M. Mahdavinejad and S. Mansoori, 2012). In extension, to high the energy consumption, a significant source of air quality sources (IAQ) can be associated with systems of air conditioning. Mushrooms and molds can be generated in the fans by the organic dust that pollutes cooling coil and condensate pan. Ditto, dirty pollutants can lead to considerable pollution problems (Santamouris, M. and Kolokotsa, D., 2013). Thus, they can potentially cause “Sick Building Syndrome” (SBS) (Hughes, B.R. and Ghani, S.A., 2011). For such problem, passive cooling (natural ventilation) systems can be a hopeful alternate to decrease the energy consumption and the best for human health with a sufficient thermal comfort.

Natural ventilation is a system that is design to relieve the problems that generated from air conditioning systems and reducing the building energy consumption. Figure 1.1 shows illustration of a simple naturally ventilated for the building, showing a number of interacting factors, such as wind and temperature stratification, which can have an important impact on ventilation system design. The two main functions of the concept of natural ventilation are (a) good indoor air quality (IAQ) with no current requirement to drive air and (b) increase thermal comfort through ventilation (L. Ryan and N. Campbell, 2012; A. Doroodgar et al., 2012).

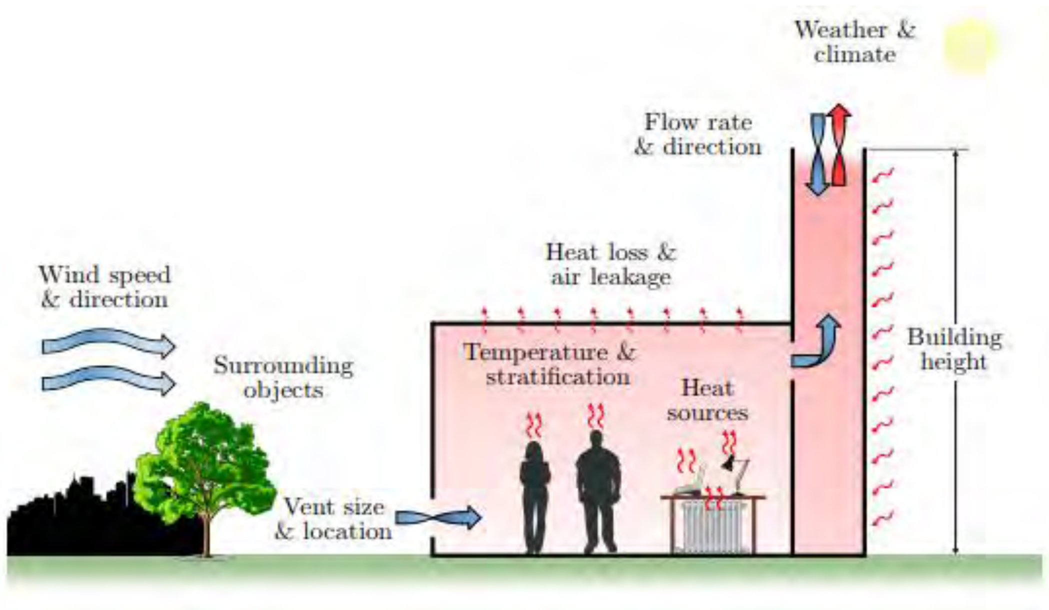

Figure 1.1: A simple natural ventilation system.

Today, for likely architecture, architectural design instituted on environmental aspects, natural ventilation is increasingly used to decrease non-renewable energy consumption. It is influential measurement to get better IAQ. Conception of ventilation changes the air inside the space of an enclosed, and air should be continually removed and substituted with new air from a cleanly source like source of the external to maintain valid IAQ, which can be known as a case wherever no known the pollutant are sitting at hurtful concentrations. The ventilation poorness can reason condensation, excessive humidity, overheating, smokes, pollutants, and a condensation of odours. In buildings of industrial and commercial, ventilation is very energy-intensive “Heating, Ventilation and Air Conditioning” (HVAC) system. In buildings of household, the main ventilation process is renewable in the form for air exchange through wind towers, openings, and windows. Defined the wind tower “as a device, which facilitates the effective use of natural ventilation in a wide range of buildings in order to increase the ventilation rates”. Towers of wind have been utilized in the hot and dry areas for much centuries to supply passive cooling (natural ventilation), then achieve thermal comfort.

One of the oldest natural ventilation systems that is still being used today is wind catcher. Traditional wind catchers are made up of various components, inclusive openings, roof, head, channel and internal partitions as shown in Figure 1.2. (Masrour, M.M. et al., 2012; Zarandi, M.M., 2009). By impacting differences of the pressures and buoyancy effects, enough ventilation of constructions can be ensured by windcatches.

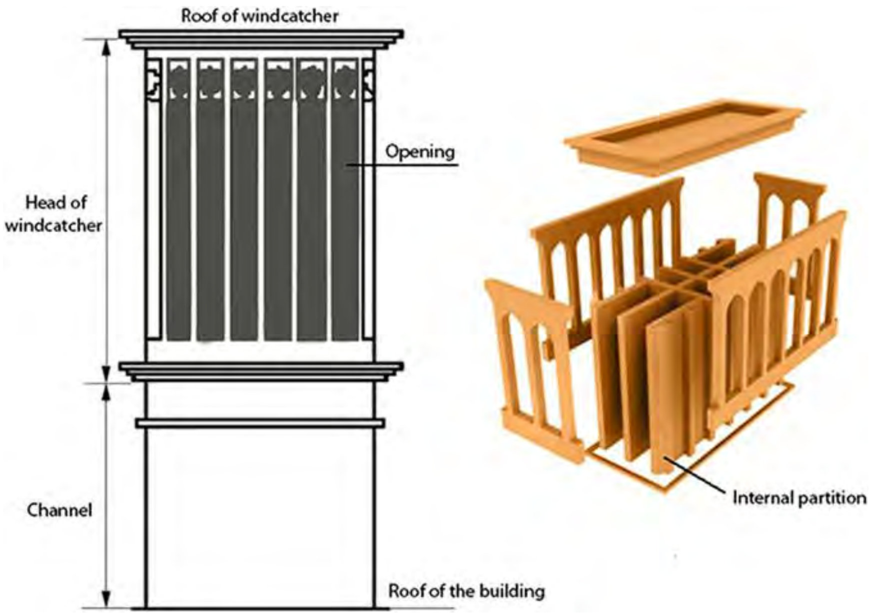

Figure 1.2: Different components of traditional wind catcher (Masrour, M.M. et al., 2012).

From the literature review, one of design of natural ventilation methods uses and combines a windscreen while solarchimney like a mechanical eco-concept that is a clear notion to increase the natural ventilation for spaces of enclosure. In the previous, one of the elements was typically utilized in designs of architectural to aid natural ventilation. However, with this combination, a more efficient aeration system can be achieved which is mentioned in natural aeration systems (Ansar, H. et al., 2017). (Meir and Roaf, 2003) explains that the wind catcher works or repair with changes in temperature of air and weight difference outside and inside that trap (Meir, I. and Roaf, S., 2003). The weight difference of air drives a process of suction in that one the airflows either downwards or upwards.

This study suggests a new design that utilized natural ventilation and ground cooling system that integrate a wind catcher and solarchimney with air cooling underground heat exchanger in a single storey building. This new design might benefit the resident from natural ventilation strategies for thermal comfort and (IAQ) in a building, in a way it would decrease consumption of energy and reducing the “Greenhouse Gas” (GHG) emissions particularly CO2 emissions that help to overcome world pollution problem.

1.2 Problem Statement

In the past, most of the thermal comfort of a building was controlled by the conditioner of air that expends a great deal for energy and consequently "Greenhouse Gas" emissions, in particularly CO2 release from fossil fuel that buildings are consumption, the trend of global warming further intensified and impacted on communities, nature and the environment. In recent years, researchers have been tackling this problem by designing new way of achieving a building thermal comfort by passive cooling system or naturally ventilated system. In all climatic regions of the world, natural ventilation proves to be the simplest and most effective way to provide thermal comfort. There are a number of natural ventilation systems such as solarchimney, wind-catcher, cross ventilation, single-sided ventilation, Venturi roof, Atrium, ventilation chimneys and top down ventilation. Design of the building itself can also contribute to passive cooling (natural ventilation) of the building. Although there are a number of studies that are looking into the design of natural ventilation system, there less studies that look into the combined system between two types of natural ventilation systems. Therefore in this study will look into the design of the combined system of wind catcher and solarchimney for the natural ventilation system with ground cooling system. The airflow of the system will be investigated by using computational fluid dynamics (CFD).

1.3 Research Questions

In this study, explanation of many crucial related questions that are related to wind catcher and solarchimney to support and development of building thermal comfort. The summary of the research are given below.

1. How to design the combined system of wind catcher and solarchimney with underground cooling system for a single storey building.
2. How to evaluate the airflow of the single storey building that utilized the combined system of wind catcher and solarchimney with underground cooling system.

1.4 Objectives

The objective of this study is as follow:

1. To propose a design of the combined system of wind catcher and solarchimney with air cooling underground heat exchanger for a single storey building as a concept for natural ventilation system.
2. To evaluate the airflow of the single storey building that utilized the combined system of wind catcher and solarchimney with air cooling underground heat exchanger.

1.5 Scope of Work

This study will look into the design of the solarchimney with underground air path combined with the wind-catcher, all of as part for one appliance. Two types of air channel design will be proposed. The airflow with temperature distribution inside the building will be investigated using "Computational Fluid Dynamics" (CFD). The airflow of the two proposed design will be analysed and compared at various wind velocity.

1.6 Significant of the Research

A sustainable A sustainable constructing is a result of the design that focuses on rising the resource efficiency spend energy, materials, and water, whereas reducing impacts of building on health of people and environment or ambience during building's lifecycle, meanwhile the better design, construction, operation and maintenances. Solarchimney is fully applied for control, and get better the ground cooling system throughout the day and with didn't use electricity. A suitable design, the solarchimney can supply a pleasant indoor climate for several hours in hot seasons. The end output from the study is a natural ventilation system, and method that get better air quality and thermal comfort in a one-storey building. Both the porch and sun chamber concepts are used to enhance the natural ventilation of a room.

According to USEPA (Panghal, A. 2017), "Indoor Air Quality" (IAQ) refers to "the air quality in and around buildings and buildings, especially with regard to the health and comfort of building users". It know element of good indoor air quality as: (1) ensuring enough ventilation (provision and pure indoor air distribution), (2) controlling airborne pollutants, and (3) maintaining suitable thermal comfort. In the past, until the kickoff of the 20th century. Therefore, it was assumed that the inhabitants of the building was the master source for indoor air pollution due to people biofats and / or smoking. However, in today's modern world, the interior ambience consists of element such as equipment and furniture of office, interior walls, surface paints and more types of decorative parts that govern and chemicals is release in interior of room air, so can pose increased hazards of health to inmates (Chenari, B. et al., 2016). Therefore, adequate ventilation is required for maintain safe condensations of contaminant of the occupants. The removal or dilution of inner pollutants with pure outside air can control the buildup of the pollutants and prevent "Sick Building Syndrome" (SBS) (Dimitroulopoulou, C., 2012). In fact, good indoor air quality is generally a direct output of natural ventilation (Zhou, J., 2008), which depends mainly on supply of new air. Note the amount of the ventilation needed to provide enough IAQ be based on the rate of the pollutant in the room. It is famous that level of pollution decreases exponentially with average of air flow. Figure 1.2 shows the exponential rate of pollution rising (Hughes, B. R. et al., 2011).

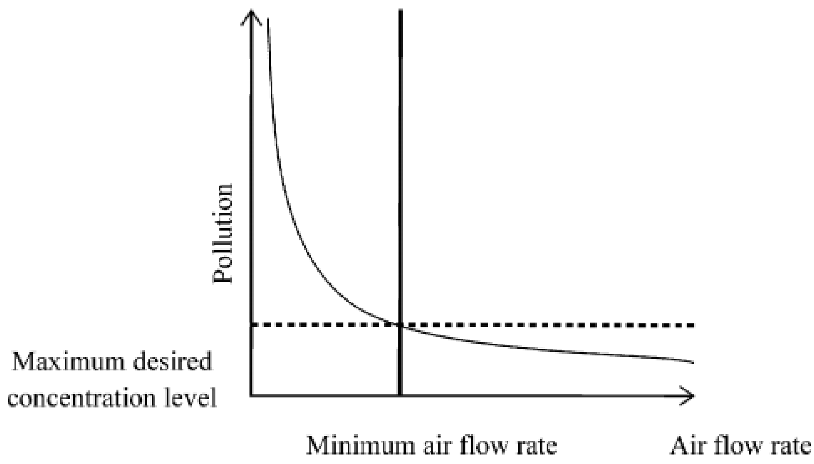

Figure 1.3: Natural ventilation for indoor air quality (Hughes, B. R. Et al., 2011).

1.7 Dissertation Structure

The two stages in this study which is P1 and P2. In the stage of P1, the project exceedingly focuses on the first three chapters of this study which is: the introduction, literature review and methodology. This stage, the problem statement, objectives, scopes, and any information or knowledge related to the project are been collecting form the various sources. Meanwhile, the P2 stage includes the chapter that covers the result and discussion of the project. In this stage, the conclusion and any recommendation also been discussed. Figure below shows the study development planning in completing this study covering the P1and P2.

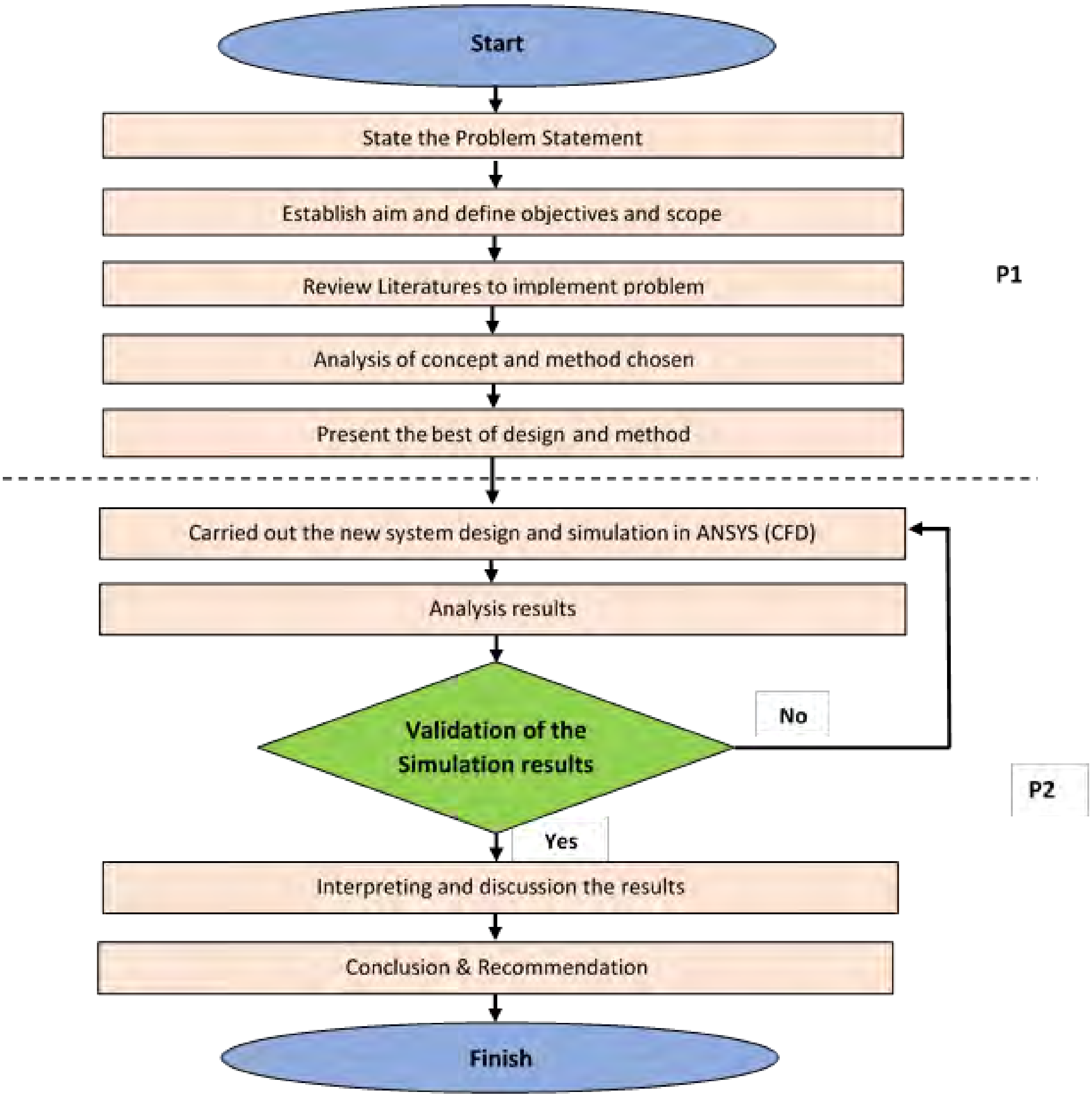

Figure 1.4: Flow chart of the study

1.8 Summary of Study

This study suggests employing the principles of a requisite (wind-catcher) integrated with a (solarchimney) to provide natural ventilation and to create cooling air through subterranean heat exchanger in a one-story building. The goal of this system is to reduce energy consumption and to profit from a health, system of natural cooling that has offered to people free of charge. In order to minimize dependence on the energy of resources of non-renewable for household cooling systems, and thus reduce global warming, it may be considered to use natural ventilation systems in combination. Wind-catchers are standalone systems that are widely applied within hot, dry areas and hot, humid or wet climates. Otherwise, a (solarchimney) is a natural manner to improve ventilation through effects of thermic buoyancy on the air. Meanwhile and through the areas of room wherever the circulating speed of wind is low, a solarchimney in integration with a windcatcher can be installed to get better that efficiency of passive cooling system, especially areas of living spaces where the speed of wind is low is roughly stagnant. To get better that efficiency of like as the system, a solarchimney can be inaugurated in the part of the building wherever the air has decelerated down. This project has conducted simulations on such a combinatorial windbreak solarchimney system to assess the air flow of the single storey building using the combined system of windscreen and solarchimney in a hot, humid climatic condition.

The first chapter presents the main topic of this research. A chapter discusses the research background, the problem statements, the purpose, scope and significance of the study, the importance of research and the general structure of study are also presented in this chapter.

Chapter two presents the literature review on renewable energy, natural ventilation, solarchimney ventilation, and windcatcher. This chapter gives an overview of natural ventilation and the concept of natural ventilation. This chapter covers all aspects of ventilation with the aim of providing a comprehensive overview of solar and wind ventilation. Literature reports about the work of former researchers will also be discussed.

Chapter three discusses the research design and methodology that has been implemented in the windcatcher with the solarchimney study. The justification for choosing the methodology for this study is also being elaborated. Furthermore, the development of the basic model, procedures, assumptions, limitations, conditions and the general setup of the pilot test and the CFD simulation are described.