CHAPTER I
INTRODUCTION

1.1 Background

Mass concrete has been widely used for construction, especially in hydroelectric and hydraulic engineering. The reason is its capability of bearing immense compressive stresses, which is essential for the integrity of large sections such as dams, foundations, and retaining walls. Mass concrete refers to any large volume of concrete with minimum dimensions typically exceeding one meter, which requires special measures to manage temperature gradients and thermal stresses [1]. This type of concrete is commonly used in infrastructure projects where high compressive strength is crucial. However, due to its substantial volume, mass concrete generates significant internal heat during the hydration process of cement. Without adequate temperature control, this can lead to uneven temperature distribution, increasing the risk of cracking and compromising the structural stability and durability of the concrete [2].

Due to the large size of mass concrete, it is challenging to control the temperature rise caused by the generation of heat from hydration. The heat of hydration is the thermal energy released when cement chemically reacts with water in an exothermic process. This reaction generates considerable heat, especially within the core of mass concrete, where heat struggles to dissipate quickly [3]. The rate at which heat is produced depends on several factors, including cement type, cement content, and ambient conditions. If this heat is not managed effectively, it can create temperature differentials between the concrete’s core and surface. These temperature gradients induce thermal stress, which can lead to cracking or even structural damage if left unaddressed [4]. Thus, managing the heat of hydration is essential to avoid compromising the integrity of mass concrete structures. The interior part of mass concrete tends to expand at high temperatures, while the exterior part of the concrete tends to shrink due to the lower ambient temperature. This temperature differential restricts the interior concrete's ability to expand, generating thermal stress, which can lead to cracks and compromise the structure [5].

To mitigate these effects, several techniques have been developed, including the post-cooling system. A post-cooling system is an effective approach for controlling internal temperatures by embedding pipes within the concrete and circulating cold water through them [6]. This method helps balance temperature distribution, reducing thermal gradients and minimizing the risk of thermal cracking. It is particularly beneficial in large concrete structures where cooling the core is essential yet challenging. The efficiency of a post-cooling system depends on various factors, such as flow rate, water temperature, and pipe diameter. By optimizing these parameters, engineers can achieve a more even temperature distribution across the mass concrete structure [7].

Several previous studies have investigated the use of post-cooling systems to control hydration heat and minimize cracking risks in mass concrete structures. Tasri and Susilawati [6] conducted numerical simulations to analyze the influence of cooling pipe spacing and cooling water temperature on temperature distribution and thermal stress. They found that pipe spacing significantly affects the formation of thermal gradients around the pipes, while lower water temperatures reduced overall concrete temperature but required careful control to avoid steep local gradients. Ratnawati [8] performed an experimental comparison of cooling pipe materials, including PVC, PEX, and steel, under constant flow and temperature. The findings emphasized that material thermal conductivity plays a significant role in cooling performance, with steel pipes being the most effective in reducing internal concrete temperature.

While numerous studies have examined the effect of material and spacing of the post-cooling system pipe, the influence of Reynolds number has not been fully explored. The flow characteristics of cooling water are crucial to the effectiveness of a post-cooling system, with the Reynolds number determining whether the flow is laminar, transitional, or turbulent. A higher Reynolds number, indicating turbulent flow, enhances convective heat transfer between the cooling water and concrete by disrupting the thermal boundary layer. This promotes more uniform flow, reduces stagnant regions, and increases the Nusselt number, which measures heat transfer efficiency [9]. As a result, turbulent flow significantly improves the overall cooling performance of the system. In this study, we aim to investigate the effects of varying pipe cooling fluid velocity, as this directly impacts the Reynolds number and, subsequently, the effectiveness of the post-cooling system.

1.2 Problem Statement

The uneven distribution of temperature in mass concrete caused by hydration heat can result in cracking, leading to reduced structural durability. Post-cooling systems have been used to address this problem. However, the effect of different pipe diameters and fluid velocities, represented by Reynolds numbers, on cooling efficiency has not been fully explored. This study aims to fill this knowledge gap by investigating how various Reynolds numbers affect temperature distribution and thermal stress in mass concrete when cooled using post-cooling systems.

1.3 Objectives

The objective of this research is to investigate the effect of cooling fluid Reynolds numbers on the temperature distribution and thermal stress in mass concrete.

1.4 Outcomes

The outcome of this research is a deeper understanding of how varying Reynolds numbers influence temperature distribution and thermal stress in mass concrete, leading to the identification of flow conditions that optimize cooling performance and minimize cracking risk.

1.5 Problem Scope

The problem scope of this study are as follows:

1. Calculations are conducted numerically using ANSYS software.
2. Cooling pipe is placed in hexagonal arrangement, the regions at the middle of two cooling pipes are thermally symmetric and no heat pass.

3. The distance between the two cooling pipes in this study is 1 m, while the length of the hexagon cylinder is 100 m.

1.6 Writing Systematics

This proposal is divided into three chapters. The first chapter contains the background for selected topic, problem statement, objectives, outcomes, problem scope, as well as an explanation of the structure of the following chapters. The second chapter discusses an explanation of the literature that supports the research. Meanwhile, the third chapter explains the steps that will be taken to do this research.