Universidad de los Andes

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Nombre Alumno

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Profesor Guía: Nombre profesor guía

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Devotion

Abstract

Acknowledgements

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Chapter 1

Introduction

Introduction

Concrete is ubiquitous: it can be found in every house, town, city, and country, regardless of the level of development, wealth, or political foundation of the region. It is such a versatile material—initially fluid, but hardening over time into a rock-like solid—that it can be used in countless applications, from the foundation of a small house to the construction of bridges and skyscrapers. Concrete is composed of three main components: cement, water, and aggregates (such as sand, gravel, or stone). Combined, they form the most widely demanded construction material in the world, with demand expected to continue increasing in the coming decades [CITAR].

Cement production alone is responsible for (PONER PORCENTAJE) of global CO_2 emissions. When the water demand and the emissions from construction activities are also considered, it becomes clear that concrete production accounts for a significant percentage of annual CO_2 emissions worldwide. For this reason, several restrictions and sustainable practices are being adopted, such as the use of recycled aggregates or alternative cementitious materials (e.g., fly ash, slag, or silica fume), which reduce the amount of cement required in concrete production and extend the service life of structures.

Concrete exhibits excellent compressive strength (around 30 MPa) but relatively poor tensile strength (around 3 MPa). To overcome this limitation, steel reinforcement is commonly used to enhance tensile resistance. However, reinforcement introduces durability issues, as steel is prone to corrosion. Chlorides can penetrate the porous structure and microcracks of the concrete, leading to steel corrosion, a reduction in structural integrity, and increased maintenance costs.

Ultra-High-Performance Concrete (UHPC) has been developed to address these challenges, with the aim of improving durability and extending the lifespan of concrete structures. UHPC is characterized by very high compressive strength (around 150

MPa), extremely low permeability, and excellent resistance to environmental factors such as freeze–thaw cycles and chemical attack. These properties are achieved by incorporating high-quality materials such as silica fume, superplasticizers, and steel fibers, which greatly enhance the mechanical and durability performance of the composite.

Silica fume, superplasticizers, and a well-graded aggregate system increase the density of the cementitious matrix, lowering the water-to-cement ratio and reducing internal voids. This densification enhances the overall compactness of the concrete, leading to higher compressive strength and reduced permeability, due to the significant decrease in porosity. Steel fibers, in turn, are incorporated to improve the tensile behavior of UHPC (typically around 15 MPa) by providing distributed reinforcement throughout the matrix. Their inclusion has been shown to substantially enhance the post-cracking performance of the material [CITAR], allowing it to sustain higher loads and larger deformations without brittle failure. Nevertheless, the effectiveness of steel fibers strongly depends on their orientation and dispersion within the cementitious matrix. Undesirable alignment or clustering can significantly limit their contribution, reducing the tensile strength and overall efficiency of UHPC.

Currently, the study of steel fiber behavior relies primarily on experimental methods, where full-scale (1:1) specimens are tested under controlled conditions to analyze fiber orientation under specific circumstances. While valuable, this methodology is highly inefficient: it involves substantial costs, lacks scalability, and does not allow for rapid iteration across multiple variables.

To address these limitations, multiphase computational fluid dynamics (CFD) simulations are proposed as a more effective approach for investigating fiber behavior. CFD simulations make it possible to iteratively explore the influence of intrinsic UHPC properties, such as rheology, as well as external factors, including placement techniques, mold geometry, or container dimensions.

To validate the proposed CFD simulation, it is necessary to obtain experimental data of UHPC in its fresh state. For this purpose, Particle Image Velocimetry (PIV) will be employed, as currently implemented at the university by Cristóbal Maggy and Valentina Tapia. In addition, it is also essential to analyze how steel fibers behave within the fluid matrix, for which the Particle Tracking Velocimetry (PTV) technique must be self-implemented.

En esta sección de debe incluir el fundamento general de la motivación de la investigación desarrollada en la tesis. También se debe incluir la Hipótesis de trabajo, Objetivo General y específicos. (Máximo 5 páginas). Usar mismo tamaño, tipo de letra y espacio del este formato).

1.1 Hypothesis

The hypothesis addressed by this thesis is divided into the following research questions:

- RQ1:
- RQ2:

1.2 Objetives

1.2.1 General Objetive

1.2.2 Specific Objectives

a)

b)

c)

1.3 Thesis Structure

This thesis is organized into five distinct chapters, each contributing uniquely to the overarching research endeavor:

a) Chapter 1:

b) Chapter **??**:

c) Chapter **??**:

d) Chapter **??**:

e) Chapter **??**:

Nomenclature

Bibliography