# CHAPTER I
# INTRODUCTION

## 1.1 Background and Rationale

Stone dust is a waste product produced by limestone crushing plants during the process of producing coarse aggregates of various sizes. The workability, compressive strength, and optimum moisture content of stone dust with coarse particles is not significantly different from clean sand (Khamput., 2005). It is a good substitute material to reduce reserves and reduce the shortage of natural materials (Prakash and Rao, 2016) In an effort to optimize resource utilization, new applications for stone dust are being investigated to reduce stockpiling. These solutions include mixing stone dust with cement for use in the foundation, fill material (Satyanarayana, Varma, Chaitanya, and Raj, 2016), backfill material (Lee and Baek, 2023; Cai, Zhang, Shi, Chen, Chen, and Sun, 2020), flexible pavement (Satyanarayana, Prem Teja, Harshanandan, and Lewis Chandra, 2013), reinforced-stone dust walls (Sumitra and Mandal, 2015), construction materials such as brick block (Habib, Begum, and Salam, 2015) and ceramic tile fabricated (Tonnayopas, Kaewsomboon, and Jantaramanee, 2010). One established and widely used method employed in international construction practices to address permeability issues within fractured rock formations is grouting with a cement-bentonite mixture. The use of stone dust to minimize groundwater flow in rock fractures is another solution to the problem. Depending upon different regions in Thailand, stone dust is not truly acceptable in the locations where clean sand is vastly available (e.g., west and southeast of the country). Nevertheless, in the northeast of Thailand stone dust is well acceptable as a substitute of clean sand because the sand is not widely available. Care should, however, be taken to ensure that the particle size ranges, chemical compositions, particle shapes are suitable for substitution of the commonly used materials.

## 1.2 Research Objectives

The objectives of this study are to assess the mechanical of stone dust mixed with Portland cement and hydraulic properties stone dust mixed with bentonite for industrial use. The main tasks include particle size analysis, X-ray diffraction analysis, uniaxial compressive strength tests, compaction tests, direct shear, consolidation tests, swelling test, and permeability test.

## 1.3 Scope and Limitations

The scope and limitations of this research include as follows.

1) The main focus of this research is to compare the mechanical behaviour of stone dust-cement mixtures and the hydraulic performance of stone dust-bentonite mixtures.

2) The particle sizes of the stone dust are 4.75 to 0.075 mm, as obtained from quarry in Nakhon Ratchasima Province.

3) Portland cement type I is mixed with stone dust following ASTM C150 (2012).

4) Uniaxial compression tests are performed of stone dust-mixed cement.

5) X-ray diffraction (XRD) is employed to identify the mineral composition according to ASTM E1426-14e1 (2019).

6) The sphericity and roundness are determined following the ASTM D2488-06 standard practice (2006).

7) The stone dust-to-cement (by dry weight) ratio of 2:1 is primarily selected.

8) Compaction tests of fined-aggregates stone dust-mixed bentonite are determined following the ASTM D1557-12.

9) Direct shear tests of fined-aggregates stone dust-mixed bentonite are determined following the ASTM D3080-11.

10) Consolidations tests of fined-aggregates stone dust-mixed bentonite are determined following the ASTM D2435 / D2435M - 11(2004).

11) Swelling tests are conducted on saturated bentonite samples at various weight ratios and under different vertical stresses.

12) The permeability test is performed on different particle sizes of stone dust.

## 1.4 Research Methodology

The research methodology is shown in Figure 1.1 includes literature review, samples collection, particles size analysis and classification, microscopic examination, mechanical properties tests, hydraulic properties tests, discussion, conclusion, and thesis writing.

### 1.4.1 Literature review

Literature review is carried out to study experimental research on the stone dust, particle size analysis, classification, mechanical and hydraulic properties. The source of information can be obtained from textbooks, journals, technical reports and conference papers.

### 1.4.2 Samples preparation

Stone dust samples used in this research have been collected from stone crushing plant, Nakhon Ratchasima province, Thailand. Stone dust samples are collected and sealed in moisture barrier bags. Preparation for testing then takes place at the Geomechanics Research Laboratory of Suranaree University of Technology. Nakhon Ratchasima province.

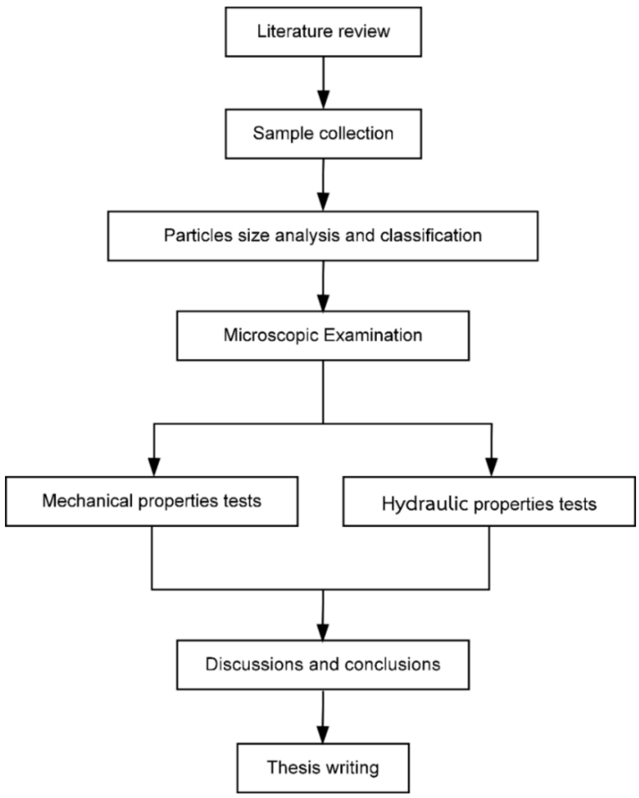


Figure 1.1 Research methodology.

### 1.4.3 Particle size analyses and classification

This investigation aims to identify the mineral composition of stone dust. X-ray diffraction analysis (using a Bruker D2 Phaser) will be conducted on samples of varying particle sizes to characterize and classify the stone dust, follow the ASTM E1426-14e1 standard practice. Minerals possess characteristic X-ray diffraction patterns, often referred to as 'fingerprints'. These patterns are archived within databases and employed by the DIFFRAC.TOPAS software to facilitate the identification of a material's composition.

### 1.4.4 Microscopic examination

The sphericity and roundness are determined from individual specimen in each size, follow the ASTM D2488-17e1 and used classification system given by Power (1982). The particle size of stone dust is observed using microscopic. Each size is scanned prior to testing mixed with cement.

### 1.4.5 Mechanical properties testing

#### 1.4.5.1 Uniaxial Compressive Strength Test

The cement mixtures are divided into two stages. Stage I is to determine the maximum compressive strength of each particle size and stage II is implemented for ease of use in the industrial sector. The ranges of stone dust sizes for stage I are 4.75, 2.0, 0.85, 0.425, 0.25, 0.15 and 0.075-mm. In stage II the stone dust is separated into coarse and fine particles. Two sets of size separations are selected. Set I, particles within the ranges of 4.75-0.25 mm are considered coarse, while those within the range of 0.25-0.075 mm are classified as fine. Set II, particles sized 4.75-0.15 mm are considered coarse, and those within the range of 0.15-0.075 mm are classified as fine. During the test, axial and lateral displacements will be monitored. The obtained data will then be used to determine the elastic modulus and Poisson's ratio. In accordance with ASTM D7012-23 standard practice.

#### 1.4.5.2 Compaction Test

Compaction tests are conducted on a range of particle sizes, from 0.25 mm to 0.075 mm. The weight ratios of bentonite to fine-grained stone dust mixtures investigated will be 100:0, 80:20, 60:40, and 40:60. The mixtures are prepared in a tray. The water is added to the mixture until the desired water content is reached. This testing procedure adheres to the guidelines established in ASTM D1557-12 for both the methodology and the corresponding calculations. Following the compaction tests, the data for dry densities and water contents are plotted. This analysis aims to identify the combination that yields the maximum dry density and the optimal water content.

#### 1.4.5.3 Direct Shear Test

Direct shear test is conducted using a direct shear device to determine the peak shear strength of the material. This test employs a vertical hydraulic load cell to apply normal stresses in increments ranging from 0.17 MPa to 0.69 MPa in a stepwise manner (0.17, 0.34, 0.52, and 0.69 MPa) The testing methodology and subsequent calculations adhere to the standards outlined in ASTM D3080-11. Following the test, the peak shear strength value will be employed to determine the material cohesion and friction angle through subsequent calculations.

### 1.4.6 Hydraulic properties tests

#### 1.4.6.1 Consolidation Test

Consolidation test is conducted on compacted specimens comprised of bentonite-fine grained stone dust mixtures. The compaction process for each specimen utilizes its respective optimum water content. Specimens are then installed within a consolidation cell and subjected to constant stresses ranging from 10 kPa to 1280 kPa in a stepwise manner (10, 20, 40, 80, 160, 320, 640, and 1280 kPa). Each stress level is maintained for a duration of 10 days. The test methodology and subsequent data analysis are performed in accordance with ASTM D2435 / D2435M - 11(2004). The test results are employed to determine the axial strain, density, and void ratio of the specimens.

#### 1.4.6.2 Swelling Test

To assess the swelling behavior under vertical stresses, a compacted mixture is subjected to a static load ranging from 2 to 6 kilograms in a stepwise manner. The test methodology and corresponding calculations adhere to the guidelines outlined in ASTM D4546-08 standard practice.

#### 1.4.6.3 Permeability test

Permeability test employs standpipes of varying diameters (6 mm, 10 mm, and 13 mm) to determine the internal cross-sectional area for permeability calculations. Water flows from the standpipe through a compacted specimen contained within a mold having a diameter of 101 mm and a length of 122 mm. To ensure consistent permeability throughout the specimen, to achieve consistent compaction, the test material will be compacted in three layers of approximately equal heights using a rammer. This procedure adheres to ASTM D2434-68 standard practices.

#### 1.4.7 Discussions and conclusions

This section presents the key findings and compares the results of the different test conditions. By analyzing the data, the influence of varying stone dust particle sizes on the performance of the new material will be discussed. This evaluation aims to inform potential field applications of the stone dust-cement mixture.

#### 1.4.8 Thesis writing

Comprehensive record of all research activities, methodologies employed, and the resulting data will be compiled and documented within the thesis. The research findings are intended for publication in either conference proceedings or peer-reviewed academic journals.

### 1.5 Thesis contents

Chapter I establishes the context of the research by outlining the background and significance of the problem. It will clearly define the research objectives, methodology, scope, and any limitations of the study. Chapter II provides a comprehensive overview of existing research relevant to the study. It summarizes the key findings and insights gleaned from the literature. Chapter III details the materials utilized in the research and the specific procedures followed for sample preparation. Chapter IV focuses on the mechanical properties of stone dust mixed with Portland cement, specifically in the context of construction applications and also outlines the laboratory testing procedures employed in the investigation, along with a presentation of the corresponding test results. Chapter V focuses on the hydraulic properties of stone dust mixed with bentonite for industrial use and outlines the laboratory testing procedures employed in the investigation. Presents a detailed analysis of the data obtained from the laboratory testing. Chapter VI provides a comprehensive discussion of the research findings, drawing conclusions based on the analysis of the data. It will also offer recommendations for future research endeavors in this area.