CHAPTER I
INTRODUCTION

1.1 Background

Thailand is a country under developing which requires a remarkable progress in implementation of multilayer large public infrastructure projects. Transportation is one of the main roots to link the roadways to the city. Moreover, land transport is the easiest way for people in Thailand to travel because of the affordable price of traveling and owning vehicles. While the demand for using vehicles still increases annually, the new road constructions also grow yearly. In contrast, investment on pavement and maintenance project are the most expensive infrastructures, which essentially needs tremendous of quarry stones to construct and can be estimated the amount of aggregate uses in pavement construction approximately between 60 to 80 percentages. A huge number of natural resources has been extracted to manipulate in construction industries rapidly, which must be operated with large machines that requisite significant fuels and identically, continue causing many environmental impacts in unpleasant ways result in climate change from greenhouse gas emission. Therefore, Thailand's government policy has encouraged to find many alternatives to reduce 30 percentage of carbon emissions in 2030. For this purpose, a sustainable infrastructure will be introduced as a key strategics initiative and at the forefront of pavement industries and researcher to be comply with the circular economy.

According to The Nation Thailand in 2021, the budget of 175.85 billion Thai baht counted as 5.7 percentages of the total budget in 2022 has been managed to use in transportation ministry, which illustrates that massive amount of budget has been promoted for road construction. Pavement structures based on constituent materials are divided into two different types which are flexible pavement (asphalt

concrete pavement) and rigid pavement (concrete pavement). Focusing on concrete road, the components to build the concrete are fine aggregate, natural coarse aggregate (NCA), cement and the water, which NCA contains the most ratio compared to overall materials that has the role to strengthen the concrete and correspondingly to fine aggregate and cement which has the role to bond and fill the gaps between granular materials. Recycled concrete aggregate (RCA) is a great substitution for NCA, which is the waste from demolished buildings or old concrete roads and tested samples from concrete ready-mix plants to reuse. Concrete waste is not biodegradable material that requires a massive land to store, and researchers have been studied on RCA to be used in construction application because of its physical stiffness as a sustainable and environmentally eco-friendly pavement. However, the service life of the pavement is dependent on the volume of usage which separates into heavy traffic volumes (greater than a million traffic loads) and lower traffic volumes (less than ten thousand loads). Excluding compressive strength, there are few more factors to shorten its service life and lose of interest such as creating high greenhouse gas emission, low tensile, low flexural strength, and fatigue life (Chan et al., 2019; Krishna et al., 2014). Thus, to prevent its weakness, thicker thickness is required to resist immature failure due to axle loading of the vehicles. For this purpose, pavement engineers and researchers have been developed technologies and methods for improving flexural strength, for instant, synthetic fibers (steel and glass fibers, polyolefin fibers, and polyvinyl alcohol fibers) have been proven as effective and increasingly used as fiber-reinforced concrete (FRC) pavement. Conversely, producing a large number of synthetic fibers requires high energy consumption and causes heavy pollution to the environment. Hence, the use of natural fibers will be a replacement with the enlargement of interest in both academic research and industrials applications.

At current years, there have been significant developments in the field of sustainable construction materials, such as innovation involving the incorporation of PET plastics and waste tires in concrete pavement (Saikia and De Brito, 2012; Youssf et

al., 2016). Waste tried can be made into crumb rubber particles and used in the concrete mix as a sand replacement (Park et al., 2016). Utilizing crumb rubber lessens the need for sand mining, protecting natural resources and lessening its negative effects on the environment. PET plastic bottles can also be broken down into small particles and used as a coarse aggregate replacement in the concrete mix (Islam et al., 2016). However, the utilization of PET and waste tires in concrete mix resulted in the reduction of flexural strength (modulus of rupture) of concrete, which is an important property for concrete pavement. Therefore, additional additives might enhance the properties of concrete in rigid pavement applications. In terms of sustainable road construction, Yaowarat et al. proposed an innovative idea of value-added natural rubber latex (NRL) as a green additive and studied the influence of various ratios of rubber-to-cement (r/c) on the development of strength of nor-mal concrete (Yaowarat et al., 2021). It indicated that the ideal rubber ratio in concrete could improve concrete's modulus of rupture, resulting in the long service life of the rigid pavement.

Nevertheless, in recent years, hemp has the potential as a cash crop globally and Thailand government has been promoted farmers to cultivate with perceived utilization in downstream industries for various purposes. Consequently, hemp will not be easily adopted by farmers until value-added processing is established. In current situation, hemp has been sold in the form of straw and seeds which will not produce significant revenue to attract farmers, whereas promoting financially hemp processing business is one of the best methods to claim the interest in hemp cultivation. To strengthen the social economic if agricultural sector in Thailand, the possibility of studying of using hemp fibers in wide-reaching as the construction industrial materials might vitalize the publics and private sectors to invest in the cultivation of an industrial crop. The hemp fiber reinforced material application has been studied in the construction fields such as lime-hemp plaster, hemp concrete, hempcrete, polymeric hemp-based composite and lightweight hemp concrete, which are mostly non-structural loading applications. In contrast, to take advantages of hemp fiber-reinforced concrete in road construction has been very limited, even though pavement is the

largest construction industry in Thailand. Due to the lack of field and laboratory experimental investigation which resulted in unable to develop a new mix design method to reach the target of flexural strength and fatigue performance and a mechanistic design method for hemp fiber-reinforced concrete as a rigid pavement. To obtain the objective, compression strength, flexural strength and flexural fatigue tests will be examined with a complete set of geotechnical and pavement laboratories at Center of Excellence in Innovation for Sustainable Infrastructure Development, Suranaree University of Technology.

Subsequently, according to socio-economic and environmental development purpose, this research study aims to scrutinize the compressive strength, flexural strength, and flexural fatigue responses of sustainable hemp fiber reinforced concrete pavement using RCA at difference mixing proportion of water to cement ratio, RCA, and hemp replacement ratios. The outcome will be analyzed to provide an effective mix design method and a mechanistic pavement design method for sustainable hemp fiber reinforced concrete pavement, which can provide both economic and environmental benefits.

1.2 Purpose of the Research

The focus of this research is to develop sustainable mix designs for concrete pavement by combining hemp fiber and natural rubber latex with waste polymers such as PET and crumb rubber. This study aims to explore innovative solutions for rigid pavement construction with the following specific objectives:

I. To investigate the performance, including durability and strength, of natural rubber latex-modified concrete with crumb rubber and recycled PET plastic aggregate as a rigid pavement material.
II. To assess the effectiveness of hemp fiber reinforced concrete, utilizing recycled concrete aggregate, in terms of its structural integrity and sustainability for rigid pavement applications.

III. To explore the fatigue performance of hemp fiber reinforced concrete, employing recycled concrete aggregate, under flexural cyclic loading, aiming to understand its resilience and longevity in pavement applications.

This research is poised to contribute significantly to the field of sustainable construction, potentially leading to more environmentally friendly and durable pavement solutions.

1.3 Scope of the Research

This research aims to evaluate the effect of hemp fibers and the replacement of NCA with RCA on compression strength, flexural strength, and flexural fatigue properties of concrete pavements. The scope of this work are as follows:

I. Study the effect of setting time of cement paste in various w/c ratios with the volume content of hemp fibers.
II. Study the effect of w/c ratio, hemp fiber content using RCA content, and waste polymer concrete using natural rubber latex on the compressive strength and flexural strength development under static loads of normal strength concrete pavement.
III. Investigate the bonding behavior of concrete materials by using SEM for hemp fiber reinforced-concrete and natural rubber latex-modified concrete.
IV. Study the effect of w/c ratio, hemp fiber content, and RCA content on the fatigue performance and crack mechanism under cyclic load test of normal strength concrete pavement.
V. Propose the practical mix design and design method for concrete pavement using hemp fiber and recycled concrete aggregate as a sustainable material.

1.4 Research Questions

The current research raises several questions to achieve research objective:

I. How does natural coarse aggregate (NCA) have negative effects to the environment?
II. How many tons of waste concrete are at cement plant and demolishment of concrete structure?
III. How to recycle concrete waste for use in the construction industry?

IV. Can waste polymer such as PET and crumb rubber be used in concrete?
V. Can natural rubber latex improve the mechanical strength of concrete?
VI. What is the appropriate amount of waste polymer to improve the concrete?
VII. Is there a significant strength effect on replacing NCA with RCA for concrete mix design?
VIII. Are there any changes of treated hemp fiber compared to natural hemp fiber?
IX. How does hemp FRC affect the strength in difference volume?
X. How does the hemp fiber reinforce concrete response to repeated loads?

1.5 Expected Contribution of the Research

The expected contributions of the proposed research objectives are as follow:

I. Able to identify the effective treatment of hemp fiber to use as a reinforcement in concrete with the optimum amount of volume in concrete.
II. Comparison of concrete using RCA and NCA for compression strength and flexural strength to use for the pavement.
III. Able to know the appropriate amount of waste polymer usage for NRL concrete.
IV. The improvement of concrete by using natural rubber latex.
V. Able to find a relationship between flexural strength and compression strength of sustainable concrete.
VI. Improvement of the flexural strength and flexural fatigue for hemp fiber reinforced concrete and NRL Concrete.