CHAPTER 1

INTRODUCTION

1.0 BACKGROUND

Top-down cracks (TDC) are longitudinal and/or transverse cracks that initiate at the surface of asphalt pavements and propagate downward. They have been increasingly observed in flexible pavements throughout the state of Michigan. TDC are usually manifested as longitudinal cracks appearing just outside the wheelpaths. Over time, they form an extensive network of longitudinal cracks connected by short transverse cracks, which ultimately reduce the life of the pavement.

TDC are receiving increased attention throughout the world, in general, and in Michigan in particular. Some existing asphalt pavement design methods address conventional fatigue cracks, which initiate at the bottom of the asphalt layer and propagate upwards. No design method is capable of predicting or analyzing top-down cracking potential. Since TDC adversely affect pavement performance, understanding the factors that enhance their potential would be the first step that needs to be taken to improve the service life of the pavements.

2.0 OBJECTIVES

The objectives of this research are:

1. Identify the causes of TDC and the factors affecting top-down cracking potential.
2. Compare top-down and bottom-up cracking potentials.
3. Develop a model to describe the rate of TDC propagation.

To accomplish the above stated objectives, a research plan was designed and is presented in section 4.0 below.

3.0 HYPOTHESIS

Based on literature review and field observations of TDC, the following hypotheses were developed:

1. TDC are longitudinal and/or transverse cracks caused by high stress ratios at the AC surface course. Therefore, top-down cracking potential is affected by all the factors influencing the magnitude of the induced tensile stress and the tensile strength of the AC mix.
2. Mechanistic analysis can be used to ascertain the factors that result in high tensile stress at the pavement surface, while laboratory investigation can be used to determine the factors that result in low tensile strength of the mix.

To accomplish the study objectives and to verify the hypotheses, a research plan was drawn and is presented in the next section.

4.0 RESEARCH PLAN

To verify the hypotheses and to accomplish the objectives of this study, a research plan was developed and is shown in Figure 1.1. A detailed summary of each activity is presented below.

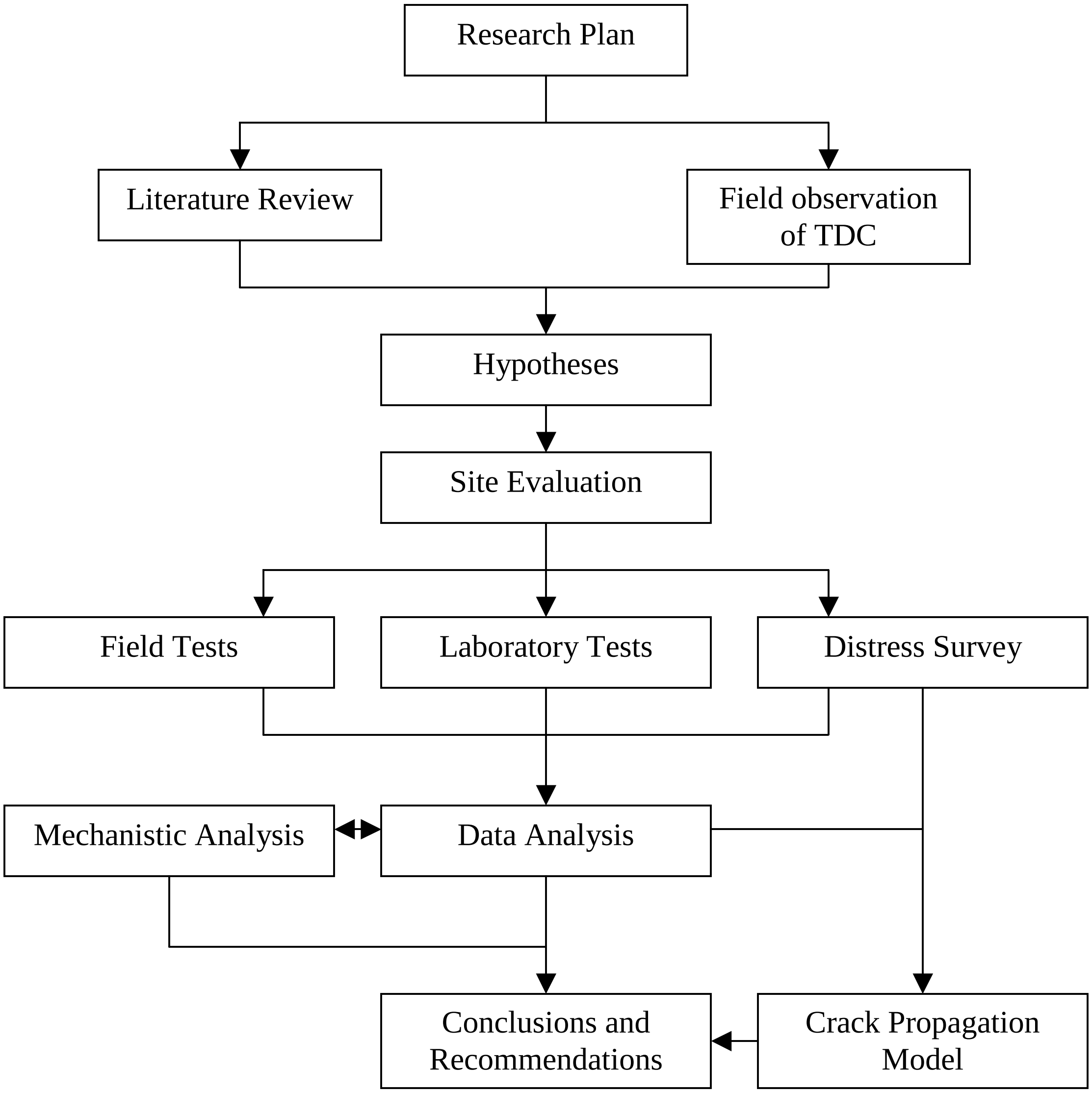

Figure 1.1 Flowchart of the research plan

4.1 Literature Review

A comprehensive literature review was conducted to determine the types of research activities that were undertaken to study the factors that affect the initiation and propagation of top-down cracking. Said review is presented in Chapter 2.

4.2 Field Investigation

The field investigation activities include:

1. Test Site Selection – In this activity, various pavements were examined to determine if they were possible candidates for the study. From the pool of candidates, 18 test sites were selected for evaluation.
2. Test Site Evaluation – The test site evaluation consisted of the following:
    - Ø Distress Survey – Included length and location of potential top-down cracks and cores taken over cracks to determine the types of cracks. Also cataloged other distresses to determine if top-down cracking occurs in conjunction with other distresses. On several test sites, multiple surveys were conducted over time to determine the rate of propagation of top-down cracks.
    - Ø Field Tests – The field tests included non-destructive deflection tests using the MDOT falling weight deflectometer (FWD), nuclear density measurements, core extraction, subsurface investigation (using hand augers) and measurements of the asphalt layer temperature, as a function of depth.

4.3 Laboratory Investigation

Laboratory testing consisted of sawing the cores to obtain test specimens, and subjecting those specimens to a battery of laboratory tests. These tests include the following:

1. Examining each pavement core and measuring its dimensions, including the thickness of each AC course, and the depth and width of cracks, if any. The total AC layer thickness was then calculated as the sum of the thicknesses of the AC courses. The results were used for the backcalculation of the pavement layer moduli.
2. Conducting specific gravity tests to determine the density of the individual asphalt courses in the pavement. The test results were used to observe density variation along and across the pavement.
3. Performing indirect tensile cyclic load tests (ITCLTs) to determine the laboratory resilient moduli of the AC courses, when possible. The test results were used to observe variations in moduli along and across the pavement as well as through the AC layer thickness.
4. Conducting indirect tensile strength tests (ITSTs) to obtain the indirect tensile strength of the AC courses, when possible. The results were used to calculate the applied stress to strength ratios.
5. Determining the asphalt content of the AC courses and the aggregate gradation of the various AC mixes using sieve analyses. The asphalt content and the recovered aggregate were obtained by incinerating the asphalt binder.

Additional tests were conducted in support of the above battery of tests (for example, theoretical maximum specific gravity tests to calculate the percent air voids of laboratory compacted specimens).

4.4 Data Analysis

Two fold analyses were conducted in this study; backcalculation of layer moduli using the measured FWD deflection data and mechanistic analyses of flexible pavements.

4.4.1 Analysis of the Measured FWD Deflection Data

The measured deflection data were analyzed in two ways as follows:

1. Determine the variations in the deflection data along and across the pavement at each test site. Results of the analyses were used to indicate the degree of uniformity in the structural capacity of the pavements.
2. Backcalculate the pavement layer moduli using the measured pavement deflections and cross-section data. The range of the resulting modulus values were used in the mechanistic analysis of the pavement structures.

4.4.2 Mechanistic Analysis of Flexible Pavements

Mechanistic analyses of flexible pavements were conducted to assess:

1. The temperature-induced tensile stresses in the AC layer.
2. The sensitivity of the load-induced tensile stresses in the AC layer to the factors affecting top-down and bottom-up cracking potentials. The results

are used to compare the crack initiation potentials at the top and at the bottom of the AC layer.

3. The influence of various factors affecting the tensile strength of the AC mixes.

4.5 Validation of the Results of the Analyses

Results of the analyses were validated as follow:

1. The accuracy of the MICHBACK computer program was checked using forward and backward mechanistic analyses.
2. For the same pavement sections and load conditions, results of the analyses obtained from finite element programs (ABAQUS and MICHAPVE) were compared to those obtained from a well accepted closed form solution program (CHEVRONX).
3. The locations of the maximum tensile stress obtained from the analyses were compared to locations of TDC observed in the field.

4.6 Conclusions and Recommendations

Based on the results of the field and lab investigations, analyses, and the understanding obtained from the literature, the proper conclusions and recommendations will be made.

5.0 REPORT LAYOUT

This report is composed of five chapters:

Chapter 1 – Introduction

Chapter 2 – Literature Review

Chapter 3 – Field and Laboratory Investigation

Chapter 4 – Data Analyses

Chapter 5 – Conclusions and Recommendations