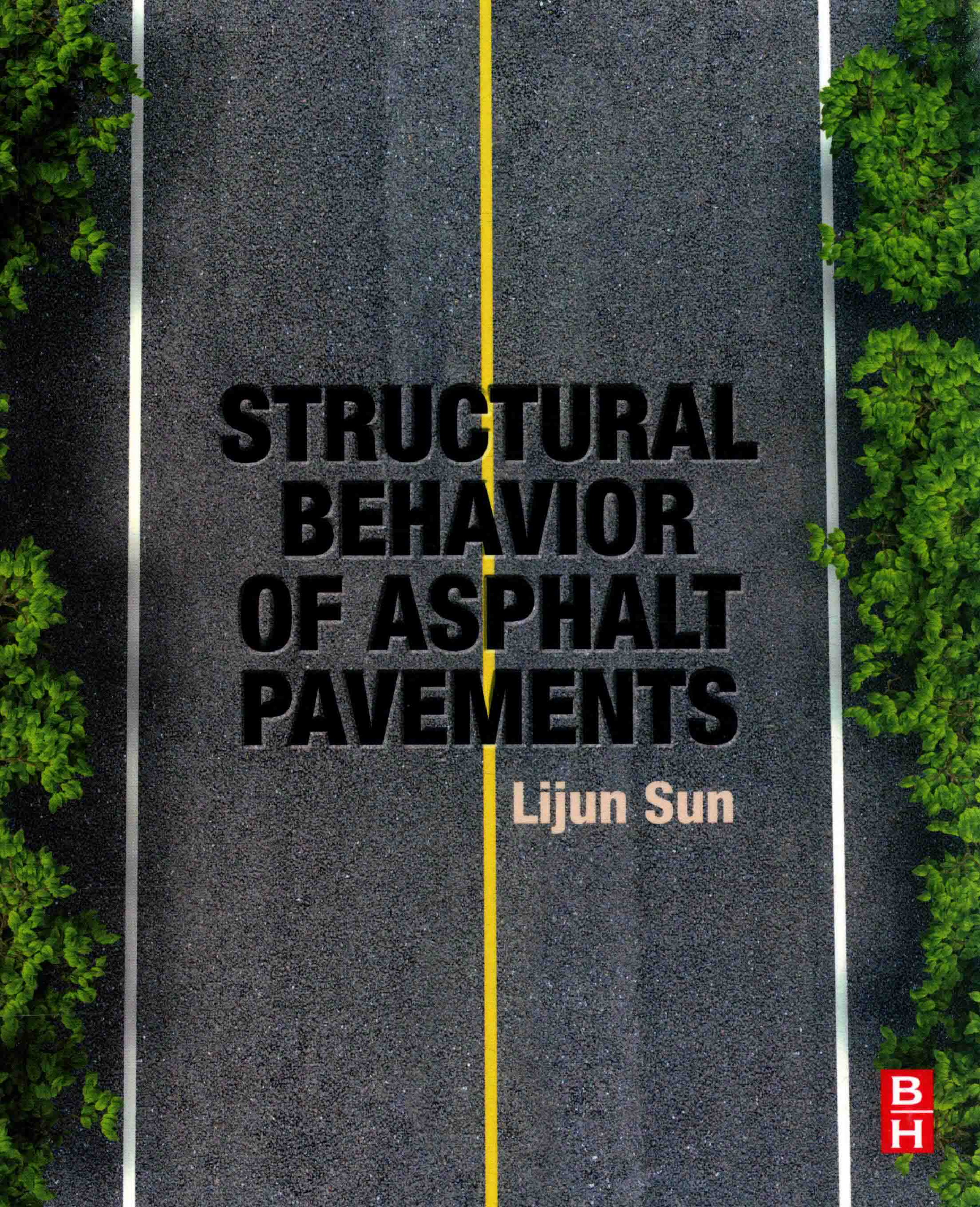

STRUCTURAL BEHAVIOR OF ASPHALT PAVEMENTS

Lijun Sun

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Preface

When current knowledge could not explain the questions we are facing, we prefer following our inner feeling to insight and grasp the beautiful essence in pavement world, and trying to shape them into science level, rather than defend tenaciously those fragmented experience knowledge although those were classical.

Since 1991, my research interests have transferred partially from the pavement management area to the asphalt pavement area. In that time, the research on asphalt pavement has had a long history and made brilliant achievements in the world. But in China, the research history on asphalt pavement was not very long, and the engineering experiences were not so rich. This is why I decided to select the asphalt pavement as my long-term research area.

With the freeway forming a whole network in China, the traffic volume and axle load magnitude has increased sharply. The national average percentage of trucks on the freeway is 40%, and the heavy weight of these vehicles causes a very serious premature distress of the pavement. Over more than two decades, many new pavement techniques, such as modified asphalt, SMA, Superpave, long-life pavement, and high-modulus asphalt, were introduced into China so promptly that the development of the pavement techniques seemed to be booming. Additionally, a large amount of research on asphalt pavement structure and material were conducted throughout the world in order to face up to the challenges from the heavy load of vehicles. Some researchers made great efforts to integrate the fragmentation pavement research results into a comprehensive theory for pavement analysis and design, but the effectiveness of this practice does not look as significant as expected. These research results are considered to be the simple extrapolation of conventional theories and methods for light-duty pavement, which is well suited for the analysis and design of conventional asphalt mixture, but not for emerging materials. These results cannot reflect the performance of pavement, nor can they give a clear guide to pavement component design; therefore they are considered only little help in solving the problems of very heavy-duty pavement structures. We face a number of questions and challenges, including: how to effectively solve pavement problems due to extremely heavy loads; how to consider emerging materials and techniques in pavement design; and how to integrate the new techniques, new materials, and new concept together for success.

With this in mind, we started our pavement research. In fact, the aforementioned challenges became the drive for us to adhere to asphalt pavement for more than two decades. The pavement world is so complicated that we cannot see the direction ahead. But in the vast mist there is always a flickering dim light leading us to pursue, not see the truth, hard to shake off. Over the years, the encourages from some predecessors excited our often languorous spirit, the doubt and controversy from some colleagues helped us improve our researches. The successful application of the research results demonstrated the value of fundamental research in pavements to decision makers, who then gave us financial support to continue. The process of rethinking, restructuring, and refining asphalt pavement helped us optimize new understanding of the pavement problems. By the end of 2001, we had finished the first stage in our research of pavement behavior, and by 2005, we had formed a clear framework on the asphalt pavement behavior. Since then, we have supplemented the research on the pavement deformation, which now forms today's pavement behavior dynamics.

The publication of this book means that the pavement research we began in 1991 is now coming to an end. The "new students" who participated in this early round of research in my group are now the "senior experts" in the Chinese highway field. With over two decades of research, we came to realize the behavioral characteristics of the asphalt pavement structure and the limits of mechanistic analysis. The asphalt pavement is so complex that the modern mechanistic theory can only help qualitatively analyze the known phenomenon, but it cannot accurately reflect the complicated performance of asphalt pavement structure and materials. Therefore, it is difficult to discover unknown laws for asphalt pavement, as any guide available is very limited in practice. This may be the basic reason that empirical analysis and design still play dominant roles in pavement practice. In order to understand the accurate behavior characteristics of asphalt pavement, it is necessary to develop a new roadmap, based on which the integration of theoretical analysis, test result, and engineering experience.

In order to better understand the behavioral characteristics of asphalt pavement, more accurate and finer theoretical analysis and tests on pavement structure and materials have been conducted throughout the world. After analyzing the impressive amount of results, we found that the scale effects (ie, continuity aspects) in the fine analysis and testing becomes more and more significant. When the pavement is considered to be a structure which is consisted of continuum materials, we can make an integral response analysis of pavement from the macroscopic point of view, while the commonly used strain/stress is a microscopic indicator, which is influenced by the inherent particle effects (granular effects) of pavement materials. This is to say that pavement materials exhibit significant "particle effects," (ie, granular effects). In the case of light traffic load, the integrity of pavement materials plays a dominant role, but in the case of heavy traffic load, especially in the case of high temperature, the particle effect of pavement materials cannot be ignored. In the pavement analysis, it is difficult to balance the integrity and particle effects in a conventional continuum mechanistic whether using the elastic or viscoelastic theory. The discrete element method permits the analysis of the interaction between the particles of materials, but it is still far from the macroscopic performance of pavement. In order to bridge the gap between the microscopic analysis and macroscopic performance, it is needed to develop a new indicator, new method, or new theory in which the mechanistic can be given with the right roles. Here, a new guideline for pavement research, "qualitative research must be correct, quantitative result should be reasonable," is put forward, and a "Bridge Principle," which can bridges the gap between the microscopic behavior and macroscopic performance, is established as a new methodology in this book. Through the Bridge Principle, the particle effects of materials are effectively avoided. In the Bridge Principle, the analysis and design parameters in pavement are re-explained to be the critical variables as a bridge, not a real response of pavement. Then, in conjunction with the tested and/or observed results, the reasonably quantified results were given. This process means that the mechanistic as a rational analysis method may be a better tool at abstracting, refining, and transplanting successful experience than as a direct design tool, thereby demonstrating a new research roadmap. With this roadmap, we conceive the logic framework in which the pavement performance and mechanistic response are incorporated together, as well as deduce the intrinsic consistency relations between the macroscopic (performance) and the microscopic (mechanistic response), structure, and material, as well as the integrity and the particle.

Our understanding on asphalt pavement came from the research practice, and gave the guide back to our research practice in time. Through the research of the past more than two decades, we defined the distress mechanism for the heavy-duty pavement and put forward the "two-way control" pavement design rule. The rule changes the conventional way for pavement component design and ensures the integral balance of resistance between pavement structure layers. We accumulated a large amount of first-hand data for the pavement performance, based on which put forward the deterioration law of pavement performance, and established the pavement behavior equation. We presented the Bridge Principle, which unifies the pavement behavior equation and the pavement fatigue equation, proving that the pavement fatigue equation is a special case of the pavement behavior equation. We believe that the Bridge Principle provides a feasible roadmap to transfer the results with various scale characteristics. Based on the Bridge Principle, we realized the transfer from test results in laboratory to real pavement performance. Through introducing a dimensionless variable to avoid the particle effects, we developed the deformation analysis equation. The pavement behavior equation, pavement fatigue equation, and deformation equation forms the entire system with an intrinsic consistency, which we call the pavement behavior equation's group. This is to say that one rule, one principle, and one equation group represents the core of new pavement theory developed in this book. These are the fruits of the joint efforts of all researchers.

The content in the book finished in different time, the research process and results in that time are persisted. Lijun Sun is responsible for all the research of the pavement issues described in this book, as well as the outline set of the book and the writing of Chapters 1, 5 (Section 5.6), 8 (Section 8.1), 10, 11.2 (Section 11.2), and 14, as well as the finalization of all chapters in manuscript. Other research participants and writers are shown in following table.

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Continued

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	5.6	Hongchao Zhang	Lijun Sun	Hongchao Zhang
	5.7–5.9	Yufeng Bi Gang Wang Hongchao Zhang	Lijun Sun	Lijun Sun
6		Xiping Liu Zhijun Xu Zijian Chen Fangyan Luo Liping Liu	Liping Liu	Lu Jia
7		Liping Liu	Liping Liu	Xiaoyang Jia
8	8.1	Liping Liu	Lijun Sun	Xiaoyang Jia
	8.2–8.5		Liping Liu	
9		Zhenglan Lu Kai Su Liping Liu Wen Tang	Kai Su	Kai Su
10	10.1–10.4	Lijun Sun	Lijun Sun	Lijun Sun
	10.5	Chunhua Hu		
	10.6	Liping Liu		
11	11.1, 11.3–11.6	Yufeng Bi Peng Cui	Yufeng Bi	Jingna Zhang
	11.2	Liping Liu	Lijun Sun	
12		Yi Wang Liping Liu Yan Xu Gang Wang	Liping Liu	Kai Su
13		Jingna Zhang Yuliang Yang Yong Peng	Yong Peng	Yong Peng
14		Lijun Sun	Lijun Sun	Lijun Sun

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