

**SIMPLIFIED APPROACH TO ESTIMATE OVERLAY  
THICKNESS FOR PRELIMINARY PAVEMENT DESIGN USING  
AASHTO (1993) METHOD**

S.A.Sugeeth Bimsara Samarasinghe

168338L

Degree of Master of Engineering

Department of Civil Engineering

University of Moratuwa

Sri Lanka

February 2021

**SIMPLIFIED APPROACH TO ESTIMATE OVERLAY  
THICKNESS FOR PRELIMINARY PAVEMENT DESIGN USING  
AASHTO (1993) METHOD**

S.A.Sugeeth Bimsara Samarasinghe

168338L

Thesis submitted in partial fulfillment of the requirement for the degree  
of Master of Engineering in Highway & Traffic Engineering

Department of Civil Engineering

University of Moratuwa

Sri Lanka

February 2021

## **DECLARATION OF THE CANDIDATE AND SUPERVISOR**

“I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature:

Date:

The above candidate has carried out research for the Masters thesis under my supervision.

Name of the supervisor:

Signature of the supervisor:

Date:

## **ACKNOWLEDGEMENTS**

Foremost I would like to express my sincere gratitude to my supervisor Dr.H.R.Pasindu for the continuous support of my research and for his patience, motivation and knowledge.

Also my sincere thanks goes to RDA for selecting me for the M.Eng in Highway and Traffic Engineering course and my current work place, Integrated Road Investment Program for providing the necessary assistance and design reports and my previous work place, Planning Division of RDA for providing the relevant test data and software.

Finally, I must express my profound gratitude to my beloved wife, Nayomi and daughter, Himaya for their continuous support, encouragement and patience throughout my years of study to complete this research work. This accomplishment would not have been possible without their unfailing love.

## ABSTRACT

In the past, Benkelman beam test is used as a nondestructive test (NDT) to investigate pavements and to do overlay designs. The main advantage of the Benkelman beam method is that using this method, an overlay design can be done without carrying out detailed investigation of the existing pavement. This is possible because, design deflections obtained from Benkelman beam test are empirically related to the overlay thickness in the Benkelman beam overlay design guideline. However, this design method has become obsolete and the field work of this test is very time consuming and labour-intensive. Thus the Benkelman beam test is not widely used at present.

At present, Falling Weight Deflectometer (FWD) test is considered as the modern nondestructive testing (NDT) method for road pavements. To do a pavement overlay design with FWD data, it is required to follow AASHTO (1993) method. To do an overlay design according to AASHTO (1993) method, resilient modulus ( $M_R$ ) of subgrade and effective structural number of the pavement ( $SN_{eff}$ ) is required. Information of subgrade conditions is required to determine the resilient modulus of subgrade ( $M_R$ ). Also thickness of the pavement layers is required to determine the effective structural number of the pavement ( $SN_{eff}$ ). This means, to do an overlay design with FWD data, using AASHTO (1993) method, a detailed pavement investigation is required. During the pavement investigations, existing pavement will be damaged to some extent.

Since pavement overlay designs can be done without a detailed pavement investigation using the Benkelman beam test, there is a motivation to do pavement overlay designs also using FWD test without a detailed pavement investigation. Hence, this research is conducted to formulate a simplified approach to estimate overlay thickness for preliminary overlay designs using AASHTO (1993) method using FWD data only. The developed method is called "Simplified Method" to distinguish it from AASHTO (1993) method.

FWD data from four road sections are used to develop the Simplified method. In this method,  $M_R$  of subgrade is determined from Surface Modulus and  $SN_{eff}$  of existing pavement is determined from Hoffman's method. The overlay thickness calculated from the Simplified method and the AASHTO (1993) method is compared with the overlay thicknesses given in the design reports.

The outcome of the research enables the Engineer to do a preliminary pavement design during the feasibility stage of a project by using only FWD data, without carrying out a detailed pavement investigation. Thus this method will help to avoid damaging the existing pavements and save time and money for pavement investigations.

**Keywords: FWD-AASHTO-Resilient Modulus-Effective Structural Number**

## TABLE OF CONTENTS

DECLARATION OF THE CANDIDATE AND SUPERVISOR .....	I
ACKNOWLEDGEMENTS .....	II
ABSTRACT .....	III
TABLE OF CONTENTS.....	IV
LIST OF FIGURES .....	VII
LIST OF TABLES.....	VIII
LIST OF ABBREVIATIONS .....	IX
Chapter 1. INTRODUCTION.....	1
1.1 Background.....	1
1.2 Problem Statement .....	2
1.3 Objectives .....	2
1.4 Research Approach .....	3
Chapter 2. LITERATURE REVIEW .....	4
2.1 Pavement Overlay Design Methods.....	4
2.1.1 Benkelman beam method .....	4
2.1.2 Road Note31 Method .....	4
2.2 AASHTO Method .....	5
2.3 Falling Weight Deflectometer (FWD) .....	5
2.3.1 Deflection basin of a pavement.....	6
2.4 Subgrade Resilient Modulus ( $M_R$ ).....	7
2.4.1 Definition of Resilient Modulus.....	7
2.4.2 Use of Resilient Modulus in AASHTO (1993) method.....	8
2.4.3 Correlation Equations of Resilient Modulus .....	8
2.5 Surface Modulus .....	9
2.5.1 Obtaining Subgrade Resilient Modulus from Surface Modulus.....	10

2.6	Deflection Bowl Parameters .....	11
2.7	AREA Parameter .....	12
2.8	Effective structural number ( $SN_{eff}$ ) of existing pavements .....	13
Chapter 3. METHODOLOGY OF STUDY.....		15
3.1	Methodology of AASHTO (1993) method.....	15
3.1.1	Overview of AASHTO (1993) Method .....	15
3.1.2	Determination of resilient modulus of subgrade ( $M_R$ ) from AASHTO (1993) method.....	15
3.1.2.1	Determination of design subgrade resilient modulus (Design $M_R$ ) from AASHTO (1993) Method.....	16
3.1.3	Determination of effective structural number ( $SN_{eff}$ ) from AASHTO (1993) method.....	17
3.1.3.1	Temperature Correction for AASHTO (1993) method.....	18
3.1.4	Determination of required structural number for future traffic ( $SN_f$ ) for AASHTO (1993) method .....	19
3.1.5	Determination of overlay thickness from AASHTO (1993) method... ..	20
3.2	Methodology of Simplified method.....	20
3.2.1	Overview of Simplified method.....	20
3.2.2	Determination of resilient modulus ( $M_R$ ) for Simplified method .....	21
3.2.2.1	Applicability of Surface Modulus method for calculating $M_R$ in Simplified method.....	22
3.2.2.2	Determination of design subgrade resilient modulus (Design $M_R$ ) for Simplified method .....	24
3.2.3	Determination of effective structural number ( $SN_{eff}$ ) for Simplified method... ..	24
3.2.3.1	Determination of effective structural number ( $SN_{eff}$ ) from	

Hoffman's Method .....	24
3.2.3.2 Temperature correction for Hoffman's Method .....	27
3.2.3.3 Corrected effective structural number (Corrected $SN_{eff}$ ) in Hoffman's Method .....	27
3.2.3.4 Applicability of Hoffman's Method to calculate $SN_{eff}$ in Simplified Method .....	28
3.2.3.5 Modification of Hoffman's Method.....	29
3.2.3.6 Method used for modification of Hoffman's Method.....	30
3.2.3.7 Data analysis for modification of Hoffman's method .....	31
3.2.4 Determination of required structural number for future traffic ( $SN_f$ ) for Simplified method .....	34
3.2.5 Determination of overlay thickness for Simplified method.....	34
Chapter 4. DATA ANALYSIS.....	35
4.1 Introduction .....	35
4.2 Calculation of overlay thickness for A001 Road .....	36
4.3 Calculation of overlay thickness for A011 Road .....	36
4.4 Calculation of overlay thickness for B133 Road .....	37
4.5 Calculation of overlay thickness for B212 Road .....	38
4.6 Comparison of results.....	39
Chapter 5. DISCUSSION .....	41
5.1 Design Subgrade Resilient Modulus (Design $M_R$ ) .....	41
5.2 Effective structural number ( $SN_{eff}$ ) .....	42
5.3 Overlay Thickness.....	43
Chapter 6. CONCLUSION & RECOMMENDATIONS .....	48
REFERENCE LIST .....	49



## LIST OF FIGURES

Figure 2-1 Schematic diagram of Benkelman Beam.....	4
Figure 2-2 KUAB FWD 50.....	6
Figure 2-3 Pavement Deflection basin obtained from FWD test.....	7
Figure 2-4 Definition of resilient modulus.....	8
Figure 2-5 Influence zone due to pavement load (P).....	11
Figure 2-6 Structural Capacity Loss over time with Traffic.....	14
Figure 3-1 Temperature correction chart for $d_0$ given in AASHTO Guide.....	19
Figure 3-2 Hog model geometry.....	25
Figure 5-1 Variation of design overlay thickness with design $M_R$ and $SN_{eff}$ for A001 road.....	43
Figure 5-2 Variation of design overlay thickness with design $M_R$ and $SN_{eff}$ for A011 road (section-1).....	44
Figure 5-3 Variation of design overlay thickness with design $M_R$ and $SN_{eff}$ for A011 road (section-2).....	45
Figure 5-4 Variation of design overlay thickness with design $M_R$ and $SN_{eff}$ for B133 road (section-1).....	45
Figure 5-5 Variation of design overlay thickness with design $M_R$ and $SN_{eff}$ for B133 road (section-2).....	46
Figure 5-6 Variation of design overlay thickness with design $M_R$ and $SN_{eff}$ for B212 road.....	47

## LIST OF TABLES

Table 2-1 Deflection Bowl Parameters (Hoak et al,1989) .....	12
Table 3-1 Road sections used in the research.....	22
Table 3-2 Percentage difference of average $M_R$ values between AASHTO method and Surface Modulus method .....	23
Table 3-3 Regression coefficients for calculation of $I_o$ .....	27
Table 3-4 Percentage difference of $SN_{eff}$ values between AASHTO (1993) Method and Hoffman’s Method .....	29
Table 3-5 Pavement stiffness categories added to Hoffman’s regression coefficient table as a new additional column .....	30
Table 3-6 Stiffness categories and Hoffman’s corrected $SN_{eff}$ equation.....	31
Table 3-7 Percentage difference of $SN_{eff}$ values between AASHTO (1993) method and Hoffman’s method .....	32
Table 3-8 Modified corrected $SN_{eff}$ equations used in Simplified method.....	33
Table 3-9 Percentage difference of $SN_{eff}$ values between AASHTO (1993) method and Hoffman’s method with modified corrected $SN_{eff}$ equations .....	33
Table 3-10 Hoffman’s corrected $SN_{eff}$ equations and modified corrected $SN_{eff}$ equations .....	34
Table 4-1 Road sections used in the design reports.....	35
Table 4-2 Stiffness category of road sections.....	35
Table 4-3 $M_R$ , $SN_{eff}$ and overlay thickness results of A001 road.....	36
Table 4-4 $M_R$ , $SN_{eff}$ and overlay thickness results of A011 road.....	37
Table 4-5 $M_R$ , $SN_{eff}$ and overlay thickness results of B133 road .....	38
Table 4-6 $M_R$ , $SN_{eff}$ and overlay thickness results of B212 road .....	39
Table 4-7 Comparison of Design $M_R$ .....	39
Table 4-8 Comparison of $SN_{eff}$ .....	40
Table 4-9 Comparison of overlay thickness .....	40
Table 5-1 Variation of Design $M_R$ .....	41
Table 5-2 Variation of $SN_{eff}$ .....	42
Table 5-3 Variation of Overlay Thickness .....	43

## LIST OF ABBREVIATIONS

<b>Abbreviation</b>	<b>Description</b>
A001	Colombo-Kandy road
A011	Maradankadawela Habarana Tirikkondiadimadu road
B133	Ganewalpola – Dachchahalmillewa road
B212	Kekirawa – Ganewalpola road
AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt Concrete
CBR	California Bearing Ratio test
COV	Coefficient of variation
FWD	Falling Weight Deflectometer
iRoad	Integrated Road Investment Program
$M_R$	Subgrade resilient modulus
psi	pounds per square inch
RDA	Road Development Authority
SM	Surface Modulus
$SN_{eff}$	Effective structural number of the pavement
$SN_f$	Required structural number to carry future traffic
SSV	Soil Support Value
ORN 31	Overseas Road Note 31